Development of biopolymeric materials for sustainable agricultural applications

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INTEMA
What challenges does Agriculture face today?
BIOESTIMULANTS

- Broad spectrum of systemic action
- Stability
- Low dose
- Controlled release
- Biocompatibles
- Micro-nano Encapsulated activators

SOLUTION
BIOESTIMULANTS
Controlled release
Low dose
Stability
Biocompatibles
Micro-nano Encapsulated activators
MICRO–NANO VEHICLES

ACTIVE PRINCIPLES

MULTIFUNCTIONAL PARTICLES

5 µm
**APDS:** Active principles delivery systems can be defined as devices capable of perform mechanisms to introduce active principles in a required places

- Act as a vehicle for a wide variety of active principles.
- Protect active principle molecules from degradation in the real field.
- Modulate the release of the active principle to achieve the desired response
- Be biocompatible and be able to biodegrade.

Active principles can be encapsulated, covalently attached, or adsorbed onto such carriers

**Polymeric Nanoparticles** are submicron size entities made from a wide variety of polymers. These devices are being extensively used as active principles carriers and controlled release systems in different fields.
Chitosan

- Linear polysaccharide
- Deacetylation of chitin
- 70-100% degree of desacetilation
- Polycation
Chitosan

Properties

- Biocompatible and biodegradable
  - Antibacterial
  - Fungicide and fungistatic
  - Low immunogenicity
  - Stimulates cell proliferation
  - Allows the transport of active ingredients

Applications

- Photography
- Cosmetics
- Water treatment
- Food industry
- (preservative, packaging ...)
- Drug-delivery systems (fibers, hydrogels, scaffolds, micro and nanoparticles ...)
- Tissue engineering
- Pesticides
Synthesis of Chitosan

Exoskeleton from Pleoticus muelleri
from fish industry waste in Argentinean Patagonia

Demineralization
Deproteinization
Deacetylation
Degree of deacetylation of the polymer FTIR

\[ N - \text{acetilación (\%)} = 31.92 \times \left( \frac{A_{1318}}{A_{1380}} \right) - 12.20 \]

\[ \text{Mw} = 1531 \pm 372 \text{ kDa}; \text{Mn} = 559 \pm 95 \text{ kDa}, \text{PI} = 1.95 \pm 0.32 \text{ by SEC} \]
SALICYLIC ACID IS A PLANT STRESS HORMONE

SA induces plant defense innate response against virus, fungus, bacteria Local and systemic responses

Antimicrobial activity

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>SA concentration</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escherichia coli, Aerobacter aerogenes</td>
<td>1 mM</td>
<td>Gershon &amp; Parmegiani, 1962</td>
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<tr>
<td>Leuconostoc mesenteroides</td>
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<tr>
<td>Staphylococcus aureus</td>
<td>0.23 mM</td>
<td>Monte et al, 2014</td>
</tr>
<tr>
<td>Streptococcus fecalis</td>
<td>0.11 mM</td>
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<tr>
<td>Bacillus polymyxa</td>
<td>&gt; 10 mM</td>
<td>El-Mougy et al, 2002</td>
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<tr>
<td>Erwinia carotovora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudomonas solanacearum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penicillium expansum</td>
<td>2.5 mM</td>
<td>Da Rocha Neto et al, 2015</td>
</tr>
<tr>
<td>Aspergillus flavus</td>
<td>1 mM</td>
<td>Panahirad et al, 2013</td>
</tr>
<tr>
<td>Rhizopus stolonifer</td>
<td>5 mM</td>
<td>Panahirad et al, 2013</td>
</tr>
<tr>
<td>Entypa lata</td>
<td>1 mM</td>
<td>Amborabé et al, 2002</td>
</tr>
<tr>
<td>Fusarium spp</td>
<td>2.5 mM</td>
<td>El-Mohamed et al, 2013</td>
</tr>
<tr>
<td>Rhizoctonia solani</td>
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<tr>
<td>Sclerotium rolfsii</td>
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<tr>
<td>Macrophomina phaseolinae</td>
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</tr>
<tr>
<td>Pythium spp</td>
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<td></td>
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<tr>
<td>Phytophthora spp</td>
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</tbody>
</table>

Da Rocha et al, 2015
Preparation of MP-SEM

CS (0.1-0.2 %, pH =3) 1% v/v HAc

Vigorous stirring

SA 0-20%

TPP solution dropwise

Spray drying
Characterization of MP – AP – average size

5%AP

10%AP

20%AP

3.30 ± 1.10

2.05 ± 0.97

1.56 ± 0.45
Thermal characterization of MPQS

A

B

C

D

13
Characterization of MPQS

<table>
<thead>
<tr>
<th>ID</th>
<th>% (w/w)</th>
<th>EE%</th>
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<tbody>
<tr>
<td>MP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MP 5% AP</td>
<td>5</td>
<td>98</td>
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<td>MP 10% AP</td>
<td>10</td>
<td>69</td>
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<tr>
<td>MP 20% AP</td>
<td>20</td>
<td>59</td>
</tr>
</tbody>
</table>

SA release from MP

SA was released from MP in a sustained way.
Particles do not exert citotoxicity in lettuce

MP-CS positively modulates root growth in lettuce seedlings

Positive effect on root growth

Dose-dependent action on the regulation of root growth

NPR1 and PR2 protein levels

NPR1: master regulator of the SA-mediated induction of defense genes

PR2: defense marker protein induced by SA

NPR1 and PR2 protein levels become increased upon treatments with particles

Citotoxicity in lettuce: a sensitive marker plant to evaluate the citotoxicity action

A

B

C

Primary root elongation (relative to H2O)

Root FW (mg)

Abundance of NPR1 (a.u.)

5 μg/ml

MP-1SA MP-5SA MP-10SA MP-20SA MP-0 CS SA

MP-1SA MP-5SA MP-10SA MP-20SA MP-0

H2O MP-0 MP-5SA

H2O MP-0 MP-1SA SA CS

-PR2

Ponceau

1st CONFERENCE ON GREEN CHEMISTRY & SUSTAINABLE COATINGS
Fusarium solani is a phytopathogen of different plant species including tomato plants.

CS-based systems exert antimicrobial activity and induce citotoxicity in F. solani spores.
Biological tests

MP-CS as a bioestimulant

Positive action on root growth parameter

Aerial Biomass
- Leaf growth
- Leaf area
- Chlorophyll content
- Performance and nutritional characteristics in fruit

Root System
- Length of the primary root
- Number and growth of lateral roots
- Fresh and dry weights

Study of the mechanistic action as a bioactive growth promoter
Biological tests

- Action on multiple root traits: Primary root, lateral root and hair root
- Improved performance compared to CS
- No citotoxicity in a wide range of concentrations
Biological tests

MP-CS improve rooting and aerial biomasses in tomato plants

Aerial dry weight

Leaf area

Root dry weight
PROMISORY ACTIONS OF CHITOSAN-MICROPARTICLES

- Spray treatment
  - Improves rooting and aerial biomasses
  - Induces antioxidant capacity
  - Enhances defense response

Chitosan microparticles generation
Nanotechnology applied to agriculture

- Activation of vegetal immunity
- Plant growth promotion
- Increased crop yield

100% natural

UNiBio

Solutiones Naturales
CONCLUSIONS

• In plant assays using chitosan synthesized particles demonstrate that have high potential to be used in the development of innovative materials for modern agriculture.

• However, we assume that it is essential to understand the mechanistic action of these materials in plants and also, to explore their action in the field.

• Field test are being carried out

• Several materials are being developed

• Patents precede Papers in all cases

• Industries are involved in several cases
CONCLUSIONS AND FUTURE PERSPECTIVES

EXTRACT

HYDROGELS

ENCAPSULATED Micro and nano

MULCH

Water remediation  Biomedicine  Textile Industry
Thank you!

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