Biochar-Fungi-Bacteria (BFB)
Soil Amendment for Food Security and Sustainable Agriculture

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SEARCA Regional Professorial Chair Lecture 2019
Southeast Asian Regional Center for Graduate Study and Research in Agriculture
Outline of Presentation

• What is **food security**?
  • issues & challenges
  • sustainable agriculture

• What is **Biochar**?

• What are **Beneficial Microorganisms**?
  • Fungi & Bacteria

• The **B-F-B** Soil Amendment

• Concluding Points
What is significant with this date?

31 October 2011
on 31 October 2011...

World's 'seven billionth baby' is born

Danica May Camacho, a girl born in Philippine capital Manila, is chosen by UN to symbolically mark global population milestone
As of 01 September 2019, 2 AM

Current World Population

7,727,218,011

view all people on 1 page >

<table>
<thead>
<tr>
<th>TODAY</th>
<th>THIS YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Births today</td>
<td>Births this year</td>
</tr>
<tr>
<td>32,032</td>
<td>93,294,810</td>
</tr>
<tr>
<td>Deaths today</td>
<td>Deaths this year</td>
</tr>
<tr>
<td>13,448</td>
<td>39,167,396</td>
</tr>
<tr>
<td>Population Growth today</td>
<td>Population Growth this year</td>
</tr>
<tr>
<td>18,584</td>
<td>54,127,413</td>
</tr>
</tbody>
</table>

Philippines

Current population: 108,359,723
(as of August 31, 2019)

equivalent to 1.4% of the total world population

ranks number 13 in the list of countries by population

Source: https://www.worldometers.info/world-population/
Estimated and projected populations of the world and its continents (except Antarctica) from 1950 to 2100.

Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.
The four pillars of food security are:

**Availability:** supply of food

**Access:** affordability and allocation of food

**Utilization:** quantity and quality of food

**Stability:** ability to obtain food over time

Declaration #4: To feed a world population expected to surpass 9 billion in 2050, it is estimated that agricultural output will have to increase by 70 percent between now and then.
WHAT DO 7 BILLION PEOPLE DO?

- Over 400 million are entrepreneurs.
- 430 million are unemployed.
- 577 million are older than 64.
- 800 million work industrial jobs.
- 1.4 billion work in agriculture.
- 1.7 billion work in services.
- 1.9 billion are too young to work (ages 0-15).

by Anna Vital

sources: cia.gov, census.gov, gemconsortium.org
CHALLENGES TO AGRICULTURAL PRODUCTION

Source: USDA, ERS and PSU calculations.

Global population growth vis-à-vis Global Consumption
“Agricultural sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs.”

Brodt et al. 2011

Maize, beans, and squash are cultivated between selectively preserved trees that provide green manure and/or fruit and/or firewood.

The practice has been shown to:
• reduce soil erosion
• increase yield
• increase biotic activity
• improve soil structure
• enhance soil organic matter accumulation

Brodt et al. (2011)
Case Study: Growing Soybeans and Forage Biomass in Quebec, Canada (Husk & Major, 2009)

• one of the largest biochar field trials in Canada

  first crop: soybean seeds (Glycine max(L.) Merr.)
  ▪ harvested four months later

In terms of yield and plant density:

20% increase in soybean plant yield
11 to 68% increase in soybean plant density

The Role of Biochar in Sustainable Agriculture, and Climate Change Mitigation for Sustainable Cities

Image: https://carolinesplantbaseddiet.com/soy-safe-eat/
Case Study: Growing Soybeans and Forage Biomass in Quebec, Canada (Husk & Major, 2009)

- one of the largest **biochar field trials** in Canada
  
  second crop: forage biomass
    - rye grass, red clover, timothy, and oats
    - harvested two months later

Table 1. Plant Above-ground Biomass

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Control</th>
<th>with biochar</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh weight</td>
<td>kg/m²</td>
<td>1.74</td>
<td>1.81</td>
<td>4.1%</td>
</tr>
<tr>
<td>Moisture</td>
<td>%</td>
<td>77.48</td>
<td>77.78</td>
<td>0.4%</td>
</tr>
<tr>
<td>Dry matter</td>
<td>%</td>
<td>22.52</td>
<td>22.22</td>
<td>-1.3%</td>
</tr>
<tr>
<td>Dry matter yield</td>
<td>kg/m²</td>
<td>0.3915</td>
<td>0.4020</td>
<td>2.7%</td>
</tr>
</tbody>
</table>


**The Role of Biochar in Sustainable Agriculture, and Climate Change Mitigation for Sustainable Cities**

## Case Study: Growing Soybeans and Forage Biomass in Quebec, Canada (Husk & Major, 2009)

### Table 2. Plant Nutritional Quality*

<table>
<thead>
<tr>
<th>Category</th>
<th>Units</th>
<th>Control</th>
<th>with biochar</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (crude)</td>
<td>%</td>
<td>12.73</td>
<td>13.95</td>
<td>9.6</td>
</tr>
<tr>
<td>Fat (oil)</td>
<td>%</td>
<td>2.48</td>
<td>2.61</td>
<td>5.3</td>
</tr>
<tr>
<td>Starch</td>
<td>%</td>
<td>4.53</td>
<td>4.67</td>
<td>2.9</td>
</tr>
<tr>
<td>Fibre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid Detergent Fibre</td>
<td>%</td>
<td>37.98</td>
<td>36.00</td>
<td>-5.2%</td>
</tr>
<tr>
<td>Neutral Detergent Fibre</td>
<td>%</td>
<td>57.11</td>
<td>53.75</td>
<td>-5.9%</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>%</td>
<td>0.97</td>
<td>1.06</td>
<td>8.5%</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>%</td>
<td>0.23</td>
<td>0.25</td>
<td>9.2%</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>%</td>
<td>0.95</td>
<td>1.01</td>
<td>6.7%</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>%</td>
<td>0.27</td>
<td>0.28</td>
<td>5.1%</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>%</td>
<td>0.19</td>
<td>0.20</td>
<td>4.4%</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>%</td>
<td>1.06</td>
<td>1.20</td>
<td>13.1%</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>%</td>
<td>0.018</td>
<td>0.016</td>
<td>-11.3%</td>
</tr>
<tr>
<td>Total Minerals</td>
<td>%</td>
<td>3.69</td>
<td>4.02</td>
<td>8.8%</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Digestible Nutrients (Weiss)</td>
<td>%</td>
<td>48.38</td>
<td>51.44</td>
<td>6.3</td>
</tr>
</tbody>
</table>

*All results are shown on a % dry matter basis.*
**Case Study**: Growing Soybeans and Forage Biomass in Quebec, Canada (Husk & Major, 2009)

Table 4. Projected Milk Production from Forage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Control</th>
<th>with biochar</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk/day from forage</td>
<td>kg</td>
<td>4.09</td>
<td>5.87</td>
<td>43.6%</td>
</tr>
<tr>
<td>Milk/metric tonne from forage</td>
<td>kg/t</td>
<td>796</td>
<td>927</td>
<td>16.4%</td>
</tr>
<tr>
<td>Dry matter yield</td>
<td>t/ha</td>
<td>0.3915</td>
<td>0.4020</td>
<td>2.7%</td>
</tr>
<tr>
<td>Milk/hectare from forage</td>
<td>kg/ha</td>
<td>312</td>
<td>373</td>
<td>19.6%</td>
</tr>
</tbody>
</table>

Table from Husk & Major (2009)
What is BioChar?

According to the International Biochar Initiative (IBI, 2006):

“Biochar is a solid material obtained from the carbonization thermochemical conversion of biomass in an oxygen-limited environments.”

- produced by thermal decomposition of organic material biomass (wood, manure or leaves)
- under limited supply of oxygen \((O_2)\)
- at relatively low temperatures \(<700^\circ C\)

Source: https://biochar-international.org/biochar/
What is BIOChar?

Ash ≠ BIOCHAR = Charcoal

soil amendment fuel
What is BIOChar?

Common materials for biochar include: hardwood, rice hulls, switchgrass, and bagasse.

Image source: https://biochar-international.org/biochar/
Anthropogenic Dark Earth
(or terra preta)
in the archaeological site of Hatahara on the middle Amazon, Brazil
(Photo by Manuel Arroyo-Kalin)

Farming Technology in Amazonia

Doyle McKey\textsuperscript{a}\textasteriskcentered and Stéphen Rostain\textsuperscript{b}
\textsuperscript{a}UMR 5175 CNRS, Université de Montpellier, Centre d’Ecologie Fonctionnelle et Evolutive (CEFE), Montpellier, France
\textsuperscript{b}Archéologie des Amériques (ArchAm), UMR 8096 CNRS, Paris, France
uses for Biochar

Amending soils

Water filtration
- bioswales
- rain gardens
- large filtration systems

Cattle feed
- reduces methane emissions

Odor control
- animal bedding
- slurry ponds
- feedlots

Erosion Control
- construction sites
- highly eroded hillsides

Images source: [Nebraska Forest Service](https://nfs.unl.edu/)
Plant growth improvement mediated by nitrate capture in co-composted biochar

Claudia I. Kammann, Hans-Peter Schmidt, Nicole Messerschmidt, Sebastian Linsel, Dietrich Steffene, Christoph Möller, Hans-Werner Koyro, Pellegrino Conte, Stephen Joseph

Biochar-mediated changes in soil quality and plant growth in a three year field trial


Biochar and biochar-compost as soil amendments to a vineyard soil: Influences on plant growth, nutrient uptake, plant health and grape quality

Hans-Peter Schmidt, Claudia Kammann, Claudio Niggli, Michael W.H. Evangelou, Kathleen A. Mackie, Samuel Abiven

Agronomy 2013, 3, 404-418; doi: 10.3390/agronomy3020404
1,201 results

Refine by:

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- [ ] 2019 (1,701)
- [ ] 2018 (902)

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biochar

Title, abstract, keywords: Biochar

Advanced search

- [ ] Download selected articles
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Research article • Full text access

Modification of biochar properties using CO2
Chemical Engineering Journal, Volume 372, 15 September 2019, Pages 383-389
Youkwan Kim, Jeong-Ik Oh, Meththika Vithanage, Young-Kwon Park, ... Eilhann E. Kwon

- [ ] Download PDF

Research article • Full text access

The effect of a biochar temperature series on denitrification: which biochar properties matter?
Soil Biology and Biochemistry, Volume 135, August 2019, Pages 173-183
Simon Welton, Daniel F. Rasse, Alice Budai, Oliver Tomic, Peter Dorsch

- [ ] Download PDF
How can we enrich?
BioChar (B) + Fungi (F) + Bacteria (B) = Enhanced Plant Growth
Our Hypothesis:

The improved growth and suppression of plant diseases by biochar amendment is linked to interactions with beneficial root-associated microbes which protect plants from pathogens and stimulate root system.
The **specific objectives** of the research are:

- isolate and identify the **soil and plant-associated fungal taxa** from soil/plant samples and evaluate their **antagonistic activities** against Fusarium wilt caused by *Fusarium oxysporum*

- isolate and identify **soil/plant-associated bacteria** from the roots, stems and leaves of *Lactuca sativa* L. var. *longifolia* (“Romaine Lettuce”) and test their production of **plant growth-promoting metabolites**

- analyse the impact of **Biochar-Fungi-Bacteria (BFB) soil amendment** on the growth and yield of an economically important plant under greenhouse condition.
Collecting soil and plant samples in a local farm in Northern Philippines.
**DA Bureau of Soil and Water Management**

**Soil Test Kit**

<table>
<thead>
<tr>
<th>Element</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>not detected</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>sufficient</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>low</td>
</tr>
<tr>
<td>pH</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Image: bswm.da.gov.ph
Isolation of Soil Bacteria & Fungi

- Bulk Soil
- Rhizosphere Soil

10 grams

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Tryptic Soy Agar (TSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungi</td>
<td>Potato Dextrose Agar (PDA)</td>
</tr>
<tr>
<td></td>
<td>Dicholoran Rose Bengal Chloramphenicol Agar (DRBC)</td>
</tr>
<tr>
<td></td>
<td>Synthetic Nutrient Agar (SNA)</td>
</tr>
</tbody>
</table>

dela Cruz et al. (2018)
The number of bacterial and fungal isolates

<table>
<thead>
<tr>
<th></th>
<th>Soil Bacteria</th>
<th>Soil Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSA</td>
<td>PDA</td>
</tr>
<tr>
<td>Bulk soil</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Rhizosphere soil</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

dela Cruz et al. (2018)

Representative isolated bacterial and fungal strains
Isolation of Plant-associated Bacteria & Fungi

- Leaves
- Stems
- Roots

1. Leaves, Stems, Roots
2. 70% EtOH 60 sec
3. 5% NaOCl 1-3 min
4. 70% EtOH 30 sec
5. Rinse 3X sterile dist. water

- Tryptic Soy Agar (TSA) [Bacteria]
- Potato Dextrose Agar (PDA) [Fungi]
- Dicholoran Rose Bengal Chloramphenicol Agar (DRBC)

dela Cruz et al. (2018)
The number of bacterial and fungal isolates

<table>
<thead>
<tr>
<th></th>
<th>Soil Bacteria</th>
<th>Soil Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSA</td>
<td>PDA</td>
</tr>
<tr>
<td>Epiphytic</td>
<td>Endophytic</td>
<td></td>
</tr>
<tr>
<td>Leaves</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Stems</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Roots</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

dela Cruz et al. (2018)

Representative isolated bacterial and fungal strains
Epiphytic vs Endophytic

- epiphytic fungi inhabiting leaf surfaces
- endophytic fungi living asymptptomatically within leaves

Yao et al. Microbiome (2019) 7:57
https://doi.org/10.1186/s40168-019-0671-0

Phyllosphere epiphytic and endophytic fungal community and network structures differ in a tropical mangrove ecosystem

Hui Yao¹,², Xiang Sun¹, Chao He³, Pulak Maitra¹,², Xing-Chun Li¹ and Liang-Dong Guo¹,²*
Endophytic Fungi

✓ promote plant growth and resistance to biotic and abiotic stresses
  • Pathogens
    (Arnold et al. PNAS. 2003, 100:15649-54)
  • Drought
  • Salinity
    (Waller et al. PNAS 2005, 102:13386-91)

✓ contribute to leaf litter decomposition
  (Purahong et al. Fungal Divers. 2011, 47:1–7)

✓ recycling carbon and nutrients in ecosystems
  (Voříšková et al. ISME J. 2013, 7:477–86)

Epiphytic Fungi

✓ contribute to leaf litter decomposition
  (Purahong et al. Fungal Divers. 2011, 47:1–7)

✓ recycling carbon and nutrients in ecosystems
  (Voříšková et al. ISME J. 2013, 7:477–86)
The number of bacteria and fungi

dela Cruz et al. (2018)
Solubilization of **Phosphorus** by Soil Microorganisms

- **P** is one of the less-abundant elements in the lithosphere (0.1% of total).  
  *Jones & Oburger, 2011*

- **P** is necessary for plant growth and development.  
  *Alori et al. 2017*

**Phosphorus Solubilizing Microbes (PSM)**

- Bacteria
- Fungi
- Actinomycetes
- Algae

**Microbial Phosphorus Solubilization and Its Potential for Use in Sustainable Agriculture**

*Elizabeth T. Alori, Bernard R. Glick and Olubukola O. Babalola*
Plant growth improvement

Aboveground

Underground

Root exudates

Production of organic acids = pH declined
(citric, oxalic, tartaric, succinic and α-ketoglucronic acids)

Sources of P
(organic and/or mineral)

Sources of K
(organic and/or mineral)

Proliferation on PSB or KSB

PSB
or
KSB

Detection of **Phosphate-solubilizing Microorganisms (PSM)**

Pikovskayas Agar
Calcium phosphate, 5 g (TM media)

Phosphate Solubilization Index (PSI)

\[
PSI = \frac{\text{colony diameter} + \text{halo zone diameter}}{\text{colony diameter}} \times 100
\]

dela Cruz et al. (2018)
## The isolated Phosphate-solubilizing Microorganisms (PSM)

<table>
<thead>
<tr>
<th>Source</th>
<th>Isolate #</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil, bulk</td>
<td>BS13</td>
<td>2.43</td>
</tr>
<tr>
<td>Stem, epiphytes</td>
<td>SEP5b</td>
<td>2.67</td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil, bulk</td>
<td>BS16aPP</td>
<td>2.66</td>
</tr>
<tr>
<td>Soil, rhizosphere</td>
<td>RS10bPP</td>
<td>2.23</td>
</tr>
<tr>
<td>Stem, endophytes</td>
<td>SEN2bPP</td>
<td>2.11</td>
</tr>
<tr>
<td>Leaf, epiphytes</td>
<td>LEP8DP</td>
<td>2.15</td>
</tr>
<tr>
<td>Stem, epiphytes</td>
<td>SEP6DP</td>
<td>2.12</td>
</tr>
<tr>
<td>Stem, epiphytes</td>
<td>SEP8DP</td>
<td>2.20</td>
</tr>
</tbody>
</table>

dela Cruz et al. (2018)
The isolated **Phosphate-solubilizing Microorganisms (PSM)**

<table>
<thead>
<tr>
<th>Source</th>
<th>Isolate #</th>
<th>PSI</th>
<th>Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil, bulk</td>
<td>BS13</td>
<td>2.43</td>
<td><em>Serratia sp.</em></td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil, bulk</td>
<td>BS16aPP</td>
<td>2.66</td>
<td><em>Talaromyces purpureogenus</em></td>
</tr>
<tr>
<td>Soil, rhizosphere</td>
<td>RS10bPP</td>
<td>2.23</td>
<td><em>Penicillium sp.</em></td>
</tr>
</tbody>
</table>

*Serratia sp.*  
*Talaromyces purpureogenus*  
*Penicillium sp.*  

dela Cruz et al. (2018)
Colony color of *Trichoderma* at higher concentrations of nickel (NiSO$_4$)

Alterations in the colony color of *Trichoderma* isolates:

- *T. asperellum* (S12) grown on TSM without (left) and with 500 ppm nickel (right)
- *T. inhamatum* (MW25) grown on TSM without (left) and with 900 ppm nickel (right)

de Padua & dela Cruz (2018)
The isolated soil and plant-associated fungi

Leptosphaeria sp.  
Talaromyces purpureogenus  
Penicillium sp.

dela Cruz et al (2018)
Antagonistic activities of fungi using dual-culture method

Inhibition Types and Point Equivalent (Wicklow et al. 1980)

dela Cruz et al. (2018)
antagonistic activities of the isolated fungi

Percentage of inhibition of growth = $\frac{r - r'}{r} \times 100$

$r$ = growth of the fungus from the centre of the colony towards the centre of the plate in the absence of antagonistic fungus

$r'$ = growth of the fungus from the centre of the colony towards the antagonistic fungus
dela Cruz et al. (2018)
<table>
<thead>
<tr>
<th>Fungal strain</th>
<th>Radial growth of fungal isolate (mm)</th>
<th>Radial growth of <em>Fusarium</em> sp (mm)</th>
<th>Inhibition of <em>Fusarium</em> (%)</th>
<th>Type of Inhibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS 13 PP</td>
<td>49</td>
<td>15</td>
<td>57</td>
<td>C</td>
</tr>
<tr>
<td>BS 14 PP</td>
<td>28</td>
<td>26</td>
<td>26</td>
<td>B</td>
</tr>
<tr>
<td>BS 16a PP</td>
<td>22</td>
<td>32</td>
<td>9</td>
<td>B</td>
</tr>
<tr>
<td>BS 16b PP</td>
<td>57</td>
<td>4</td>
<td>89</td>
<td>C</td>
</tr>
<tr>
<td>RS 10b PP</td>
<td>24</td>
<td>31</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>LEN 4 PP</td>
<td>15</td>
<td>25</td>
<td>29</td>
<td>B</td>
</tr>
<tr>
<td>LEN 6 PP</td>
<td>28</td>
<td>28</td>
<td>20</td>
<td>B</td>
</tr>
<tr>
<td>SEN 5 PP</td>
<td>37</td>
<td>15</td>
<td>57</td>
<td>C</td>
</tr>
<tr>
<td>BS 4 DP</td>
<td>42</td>
<td>23</td>
<td>34</td>
<td>C</td>
</tr>
<tr>
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*Fusarium* radial growth without the antagonist after 7 days = 35 mm  
dela Cruz et al. (2018)
<table>
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<th>Mutual inhibition upon contact (B)</th>
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dela Cruz et al. (2018)
**antagonistic activities of the isolated fungi**

<table>
<thead>
<tr>
<th>Fungal strain</th>
<th>Radial growth of fungal isolate (mm)</th>
<th>Radial growth of <em>Fusarium</em> sp (mm)</th>
<th>Inhibition of <em>Fusarium</em> (%)</th>
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</tr>
</tbody>
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*Fusarium* radial growth without the antagonist after 7 days = 35 mm  
dela Cruz et al. (2018)

**Fusarium wilt**  
(Source: http://www.oisat.org/)
- tomato and other solanaceous crops
- sweet potato
- legumes
- cucurbits
- banana
- cotton
- other herbaceous plants

**CURRENT RISK LEVELS OF TR4 FOR COUNTRIES WHERE BANANA IS AN IMPORTANT COMMODITY**

*Source:* FAO Global programme on banana fusarium wilt disease
Fusarium wilt has already affected some 2,402 hectares of banana plantations.

In 2013, Davao Region with 13,743 hectares of infected banana farms.
Fusarium wilt in Lettuce

Lettuce cultivars have varying susceptibility to Fusarium wilt, a fungal disease. When grown in infested soils, Caesar was highly disease resistant. Inset, top, Grand Max and, middle and bottom, Early Queen were progressively less resistant.

My **Take-Home Points:**

Biochar combined with microbes (B-T-B) for the soil amendment to promote plant growth & health

- **Phosphate-Solubilizing Bacterium (PSB)**
- **Pathogen-Inhibiting Fungus (PIF)**

BioChar-amended Soil + PSB + PIF

Enhanced Plant Growth

Increased Plant Yield

Food Security

My Take-Home Points:

- Increased Plant Yield
- Food Security
Committee on World Food Security (2014)

“Agricultural development is critically important to improving food security and nutrition.”

Its roles include:

- increasing the quantity and diversity of food
- driving economic transformation
- providing the primary source of income for the world’s poorest people
Acknowledgement!

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- Jeane A. dela Cruz, University of Santo Tomas
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Acknowledgement!
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The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) works to strengthen institutional capacities toward inclusive and sustainable agricultural and rural development (ISARD) in Southeast Asia through graduate education, research and development, and knowledge management.

About SEARCA

Science and education for agriculture and development

SEARCA Regional Professorial Chair Grant
Mission: Exploring Philippine Fungal Biodiversity for the Filipino Community

Vision: At the forefront of fungal research in the Philippines