The Way Forward: Smart Fertilizer Technologies for Sustainable Agriculture in the Philippines

Philippines Country Report

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Global population by 2050 is expected to reach **9.6 billion**

However, **agricultural and industrial crop yields** continue to **Decline or Plateau**
With the objective of increasing food production while preserving the environment and global climate, **smart fertilizer technologies** have become the latest trend in sustainable farming and in different research institutions in the Philippines.
BIOFERTILIZERS

- Contain living microorganisms which when applied to the soil, seed or plant surface, colonizes the rhizosphere and promotes growth by increasing the availability of nutrients to the host plant (Vessey 2013)

• Biological Nitrogen Fixers
• Plant Growth Promoters
• Fungi-based biofertilizers
Bio-N
Inoculant for Rice, Corn and HVC

• It is a formulation with the nitrogen-fixing bacteria, *Azospirillum sp.* isolated from wild sugarcane “talabib” grass, *Saccharum spontaneum*.

• Used as seed coating or as a dilute solution for root dipping or drenching at a rate of 1 pack (200g) per 3kg corn seeds or 20kg rice seeds.
**Bio-N**

Inoculant for Rice, Corn and HVC

- This could effectively reduce nitrogen fertilizer inputs by 30-50%.
- Supplementing 50%, 75% and 100% RR with Bio-N effectively increased rice yields to 3.48 t ha⁻¹, 3.67 t ha⁻¹ and 4.52 t ha⁻¹, respectively. Whereas 100% RR alone yielded only 3.67 t ha⁻¹.
- 100% RR with Bio-N increased rice yield to 4.52 t ha⁻¹ (net US$308.17), whereas, 100% RR alone yielded only 3.76 t ha⁻¹ (net US$176.16).

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(Javier and Brown, 2009; Ocampo et al., 2012; Zarate, 2009)
NitroPlus
Legume Inoculant

• NitroPlus is a formulation of *Rhizobia* cultures, capable of enhancing N fixation and N nutrient uptake by 92% -124%.

• One pack of NitroPlus could replace 2-3 bags of ammonium sulfate in legume crops.

• Applied as seed coating at a rate of 1 pack (100g) per 10kg soybean seeds, 10kg cowpea, 6kg mungbean or 50kg seeds of peanut.

(Javier and Brown, 2009; Zarate, 2009)
NitroPlus
Legume Inoculant

• Application of NitroPlus alone increased yield by:
  • 124% in soybean,
  • 29% in mungbean, and
  • 39% in peanut

• Increased net return
  • US$48 to US$170 in soybean,
  • US$52 to US$72 in mungbean, and
  • US$57 to 146 in peanut

(Javier and Brown, 2009; Zarate, 2009)
Biological Nitrogen Fixers

**Nutrio**

Endophytic Microbial Inoculant

• Nutrio is a foliar spray biofertilizer that contains Endophytic bacteria (*Enterobacter saccharii* S18), microbes residing within the tissue of plants and are capable of N fixation and plant growth promoting hormone production.

• It can substitute half of the recommended fertilizer rate in sugarcane (200 kg ha⁻¹), thereby reducing fertilizer input costs.
Nutrio
Endophytic Microbial Inoculant

• Nutrio is capable of increasing sugarcane yields and net income by 10-20%, and reduce fertilizer use by 25-50%.

• Application of Nutrio alone yielded 102.25 TC ha⁻¹. While the application of Nutrio with 50%RR of conventional fertilizer yielded 155.65 TC ha⁻¹.

(Javier and Brown, 2009; Zarate, 2009)
Biological Nitrogen Fixers

Mahogany 6mo. (A) without and (B) with Nutrio

with Nutrio without Nutrio
BioGroe

Plant Growth Promoter

• BioGroe is a microbial formulation that contains Plant Growth Promoting Rhizobacteria (PGPR)
• It aids in the solubilization of nutrients in the soil, stimulates root growth, and protects the plant by producing antimicrobial compounds
• Application of BioGroe effectively increased rice yield from 4.2 t ha\(^{-1}\) to 4.5 t ha\(^{-1}\) (dry season) and 4.5 t ha\(^{-1}\) to 4.8 t ha\(^{-1}\) (wet season).

(Javier and Brown, 2009; Banayo et al., 2012; Sta Cruz et al., 2012)
Plant Growth Promoters

MykoPlus
Multi-specie Bioferilizer

- MykoPlus is a formulation of mycorrhiza, nitrogen-fixing bacteria, phosphate solubilizing microbes, phytostimulators and other beneficial microbial colonies
- This could increase yields of lettuce from 1.4 t ha\(^{-1}\) to 1.9 t ha\(^{-1}\) and cabbage from 35.47 t ha\(^{-1}\) to 51.68 t ha\(^{-1}\)

(Cervantes et al., 2017; PCAARRD, 2015; Magtoltol et al., 2018, unpublished)
Plant Growth Promoters

MykoPlus
Multi-specie Bioferilizer

Yield of Cabbage as influenced by MykoPlus and increasing levels of phosphorus in an acid upland soil

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>MARKETABLE HEAD (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.02 b</td>
</tr>
<tr>
<td>150-0-160</td>
<td>15.36 c</td>
</tr>
<tr>
<td>150-0-160 + MykoPlus</td>
<td>19.93 c</td>
</tr>
<tr>
<td>150-50-160</td>
<td>29.53 b</td>
</tr>
<tr>
<td>150-50-160 + MykoPlus</td>
<td>45.03 a</td>
</tr>
<tr>
<td>150-100-160</td>
<td>35.47 b</td>
</tr>
<tr>
<td>150-100-160 + MykoPlus</td>
<td>51.68 a</td>
</tr>
</tbody>
</table>

(Cervantes et al., 2017; PCAARRD, 2015; Magtoltol et al., 2018, unpublished)
Fungi-Based Biofertilizers

VAMRI
Vesicular Arbuscular Mycorrhiza Root Inoculant, is a mycorrhizal inoculant

• Enhances nutrient uptake of plants especially of immobile elements P and Zn, and could replace 50-100% of the total fertilizer requirements of the crops.

• Also protects the crop from soil borne diseases commonly found in banana seedlings.

• Suitable to a wide range of crops

(Javier and Brown, 2009; Castillo and Puig, 2016; Aggangan et al., 2013)
Mykovam
Mycorrhizal Inoculant for Agricultural Crops, Fruit Trees and Forest Trees

• Mykovam is also a mycorrhizal inoculant applicable to fruit trees, forest trees, (except pines and dipterocarps) and ornamentals (except orchids).

• It is capable of replacing **60-85%** of the total chemical fertilizer requirements of the crop

(Javier and Brown, 2009; Elenan, 2015, Aggangan, 2013; Guy and Aggangan, 2012)
Fungi-Based Biofertilizers

BioSpark Trichoderma
Microbial Inoculant (BioCon)

• It enhances root absorption of macro- and micronutrients, reduce disease incidence in the crop caused by a wide range of soil-borne pathogens (Damping-off of seedlings, Durian die-back and Corn sheath blight).

• Improves seed germination, seedling survival percentage and yield outputs by 10-20%.

(Javier and Brown, 2009; Cuevas et al., 2005; Penalba et al., 2014; Banayo et al., 2012; Brown et al., 2016)
Fungi-Based Biofertilizers

BioSpark Trichoderma
Microbial Inoculant

• Reduces the conventional fertilizer usage by 50-55%, replacing approximately 2-3 bags of chemical fertilizer inputs.
• This only costs US$6.50 per 250g bag of BioSpark.
• Net income of BioSpark-applied rice could reach economic gains up to US$263.90 per hectare.

(Javier and Brown, 2009; Cuevas et al., 2005; Penalba et al., 2014; Banayo et al., 2012; Brown et al., 2016)
Smart Fertilizer Technologies

NANOFERTILIZERS

- Nutrients delivered as encapsulated within, or coated with materials of nano-scale dimensions, thereby increasing its nutrient efficiency by means of slow or controlled release of nutrients.
FertiGroe® N, P and K Nanofertilizers

• The application of FertiGroe® is similar with that of conventional fertilizers.
• FertiGroe® could significantly increase total P uptake by 50% and total N uptake by 60%.
• It also increases grain yield of corn by 40% and dry matter yield by 48% as compared to conventionally applied fertilizer treatments

(Fernando, 2018)
FertiGroe® N, P and K Nanofertilizers

Corn yield (t ha\(^{-1}\)) as influenced by varying rates of conventional and FertiGroe® nanofertilizer

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>YIELD (t ha(^{-1}))</th>
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<tbody>
<tr>
<td></td>
<td>Nanofertilizer</td>
</tr>
<tr>
<td>Control</td>
<td>0.8 c</td>
</tr>
<tr>
<td>25% RR</td>
<td>1.9 bc</td>
</tr>
<tr>
<td>50% RR</td>
<td>4.3 ab</td>
</tr>
<tr>
<td>75% RR</td>
<td>5.1 a</td>
</tr>
<tr>
<td>100% RR</td>
<td>5.2 a</td>
</tr>
<tr>
<td>125% RR</td>
<td>4.8 ab</td>
</tr>
</tbody>
</table>

(Villegas et al., 2018, unpublished)
**FertiGroe® N, P and K Nanofertilizers**

Biomass (t ha⁻¹) of **sugarcane** 5 months after the application of conventional and FertiGroe® nanofertilizer

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>BIOMASS (t ha⁻¹)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Nanofertilizer</td>
<td>Conventional</td>
</tr>
<tr>
<td>Control</td>
<td>10.58 c</td>
<td>11.23 bc</td>
</tr>
<tr>
<td>25% RR</td>
<td>12.49 abc</td>
<td>12.63 abc</td>
</tr>
<tr>
<td>50% RR</td>
<td>15.07 a</td>
<td>12.63 abc</td>
</tr>
<tr>
<td>75% RR</td>
<td>14.98 a</td>
<td>13.99 abc</td>
</tr>
<tr>
<td>100% RR</td>
<td>14.09 ab</td>
<td>15.20 a</td>
</tr>
<tr>
<td>125% RR</td>
<td>13.09 abc</td>
<td>15.12 a</td>
</tr>
</tbody>
</table>

(Sanchez et al., 2018, unpublished)
Nanofertilizers

FertiGroe® N, P and K Nanofertilizers

Plant height and rooting intensity of non-bearing coffee four months after fertilizer application (twice a month)

(Salazar et al., 2018, unpublished)
Nanofertilizers

Nano Zinc Oxide Foliar Fertilizer

- Application of synthesized nano-ZnO increased marketable yield to 11.74 t ha$^{-1}$ compared with ZnO (6.6 t ha$^{-1}$) and ZnSO$_4$ (6.22 t ha$^{-1}$)
- Synthesized nano-ZnO foliar spray could reduce the severity of black leaf mold and blossom-end rot in tomato.
- Supplementing the synthesized nano-ZnO application with B further increased marketable yield (15.25 t ha$^{-1}$) (Ybañez et al., 2018, unpublished)
Nanofertilizers

Nanoporous Zeolite from Sugarcane Bagasse Ash

- Initial characterization of the synthesized zeolite yielded higher total, external and internal cation exchange capacity (CEC) as compared to commercially available zeolite.

- Synthesized zeolite was found to be capable of being a nutrient carrier because of its porous structure, high surface area and high reactivity with nutrient ions.

(Ybañez et al., 2018, unpublished)
RADIATION-MODIFIED FERTILIZERS

- These are irradiated natural polymers such as carrageenan (seaweeds) and chitosan (crab shells), utilized as crop stimulating materials or plant growth promoters.
Radiation-Modified Fertilizers

Radiation-modified Carrageenan PGP (Carra-Vita®)

- This is an extracted carrageenan from seaweeds, irradiated to develop natural bioactive ingredients aiding in plant growth.
  - Enhances photosynthesis and stimulates root nutrient absorption
  - Provides potential resistance to Rice Tungro Virus and Rice Bacterial Leaf Blight
  - Promotes the presence of beneficial insect predators

(PNRI, 2018)
Radiation-modified Carrageenan PGP

- Increased rice yield by at least 20% and mungbean yield by 52% when combined with half of the recommended fertilizer rate.
Radiation-Modified Plant Growth Promoters

PNRI test field for rice using synthesized radiation-modified PGP

(PNRI, 2018)
While various fertilizers are being developed, various **Diagnostic and Decision Support Tools** are essential to guide farmers in applying the **right nutrient source** in the **right amounts** and **timely application** for a **specified location**.

4 Rs of Fertilizer Management:
1. Right source
2. Right amount
3. Right timing
4. Right place
Diagnostic and Decision Support Tools

Soil Test Kit (STK)

- Allows easy, low cost and quick analysis of soil salinity and soil NPK nutrient levels
- Convenient for farmers in remote areas where soil laboratories are unavailable
- Could analyze 30 samples per kit, which only costs US$ 37 per kit (US$ 1.20 each)
- Cheaper than laboratory analysis which costs US$ 20-40 per routine analysis (pH, OM, P and K) of soil

(Soriano et al., 2008)
Diagnostic and Decision Support Tools
Minus-One Element Technique

- Suitable and quick analysis of soil nutrients for flooded paddy soils
- Presents actual field conditions of P, Zn and S, which are sensitive to flooding
- MOET was able to detect multiple element deficiencies
- Only costs US$ 5.95, cheaper than laboratory analyses of N, P, K, Zn, S and Cu, which costs US$ 9.85 to as much as US$ 41.80

(PhilRice, 2002; Azhiri-Sigari et al., 2003)
Diagnostic and Decision Support Tools

Rice Crop Manager (RCM) – IRRI

- A free web-based nutrient management decision tool designed in the formulation of site-specific fertilizer recommendations and other cultural practices for rice
- Could cut fertilizer inputs from 55 to 22 kg ha\(^{-1}\) without significantly reducing grain

- Could increase grain yield by 6%, from 4.22 to 4.48 t ha\(^{-1}\), and raise net income by as much as US$ 154.00

(PhilRice, 2002; Azhiri-Sigari et al., 2003)
Diagnostic and Decision Support Tools

Nutrient Expert (NE) - IPNI

• Functions similarly as RCM, but NE is specifically designed for corn

• Could significantly increase corn grain yield from 7.5 to 9.1 t ha\(^{-1}\), with NE management guidance

• Gross returns could also significantly increase by US$ 302

(Pampolino et al., 2016)
Diagnostic and Decision Support Tools

Crop Optimized Recommendation for Nutrients (CORN) - PNRI

- CORN is a user-friendly computer software and mobile application (iFarm) designed for the generation of a site specific fertilizer recommendation.

- This also generates suitable farm management practices depending on the field, soil and management information given.
Applications of biotechnology, nanotechnology and nuclear technology to agriculture have the potential of increasing nutrient use efficiency and yield, while reducing their adverse ecological impacts.

Biofertilizers or microbial inoculants were proven to have beneficial effects to crops.

Biofertilizers also increase net returns because of their low and affordable cost, as compared with conventional fertilizers.
Summary

• Nanofertilizers, although still in the initial stages of field testing, shows the potential of increasing crop yields and reducing conventional fertilizer use.

• Similarly, the radiation-modified Carrageenan PGP showed promise in improving yields of rice and mungbean.

• Lastly, diagnostic and decision support tools are also essential in providing proper fertilizer management techniques, as well as, correct and timely fertility status of the soil.
With the current technologies available in the country, Philippines appears to be on the right track towards achieving Agricultural Sustainability.

The challenge...

Efforts should continue, particularly in exploring the applications of nanotechnology and nuclear techniques in developing smart fertilizers and making these technologies accessible to farmers.
Thank you for your attention

Maraming salamat po!