# Agricultural Biotechnology Support Project II

*Supporting agricultural development through biotechnology*

# Bt Eggplant for South and Southeast Asia: Potential Socioeconomic Benefits

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# Eggplant (*Solanum melongena* L.)

(www.hollywoodpatch.com)

(photo c/o ABSPII SEAsia)

(www.savortheworld.net)

- Belongs to *Solanaceae*, the nightshade family, which includes tomatoes, potatoes, chili, peppers
- Also known as aubergine in the West and other local names in various countries
- Exhibit a wide range of variation in colors, shapes and sizes

(www.uncorneredmarket.com)

(www.uncorneredmarket.com
)

(photo by Dave Bullock)

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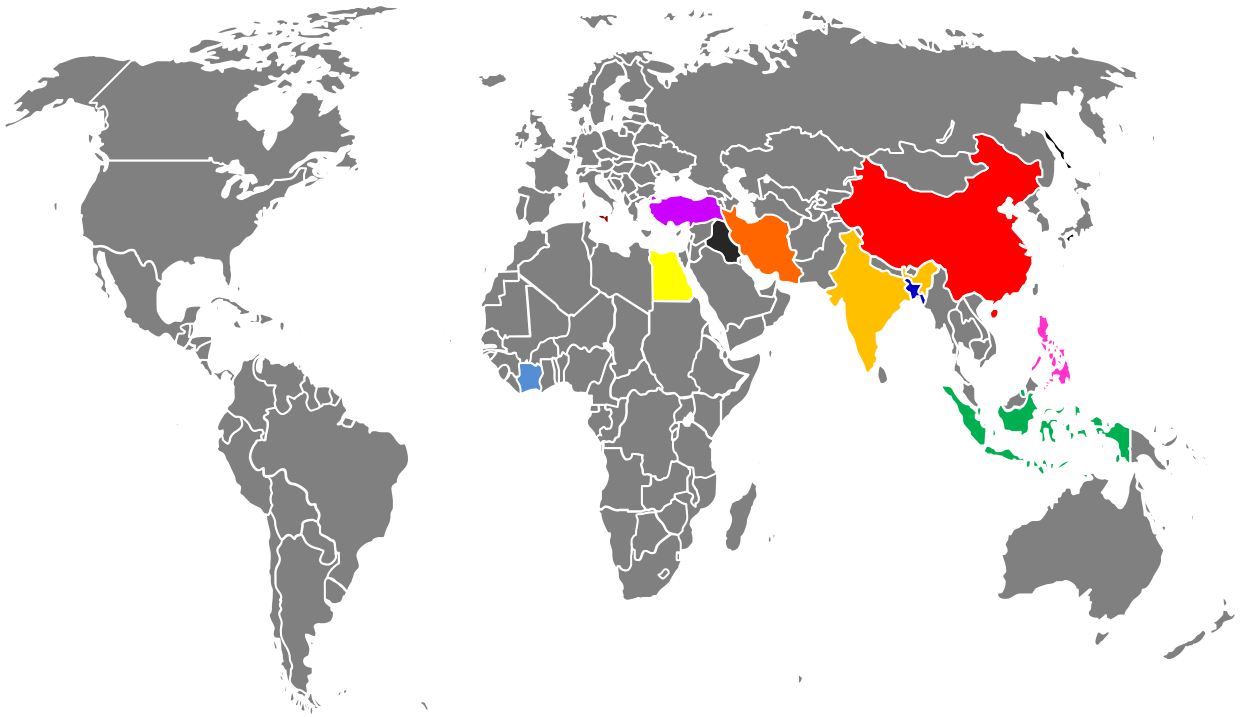
# Eggplant – The Fruit




- ✓ Very popular, economically and culturally important vegetable
- ✓ Superior in terms of fiber, vitamins and minerals; contains no fat , 25 calories
- ✓ Consumed in rural and urban areas as ingredients in many native dishes


Photo sources: ABSPII SEAsia Center, www.uncorneredmarket.com, Cornell Chronicle, www.treehugger.com, www.worldofstock.com

# Top Ten Eggplant Producing Countries
## (*Area of production, 2010*)



| | |
|---|---|
| #1 CHINA | 731,547 has |
| #2 INDIA | 612,400 has |
| #3 INDONESIA | 52,000 has |
| #4 EGYPT | 40,291 has |
| #5 IRAN | 29,300 has |
| #6 TURKEY | 28,000 has |
| #7 PHILIPPINES | 21,426 has |
| #8 IRAQ | 20,637 has |
| #9 BANGLADESH* | 17, 959 has |
| #10 Ivory Coast | 11,200 has |

**WORLD**

Area of Production: **1,660,671 has**

*Sources: FAO CropStat 2010; BBS 2010**

# Eggplant Statistics in India, Bangladesh and the Philippines (2010)

| | INDIA | BANGLADESH | PHILIPPINES |
|---|---|---|---|
| Rank among vegetables | 4th | 3rd | 1st |
| Area of Production (has) | 612,400[a] | 17,959[b] | 21,426[a] |
| Volume of Production (mt) | 1,056,000[a] | 125,080[b] | 208,252[a] |
| Yield (tons/ha) | 17.24[a] | 5.8[c] | 9.71[a] |
| Eggplant farm size (ha) | 0.71 – 2.3[d] | 0.4 – 0.6 | 0.31 – 0.7[e] |
| Estimated # eggplant farmers | 1.4 M | 90,000 | ~42,000 |

Sources: FAO CropStat 2010 [a;] BBS 2010[b] ;BBS, 2005[c]
Kumar & Prasanna, 2010[d]; Quicoy, 2010; 2012[e]

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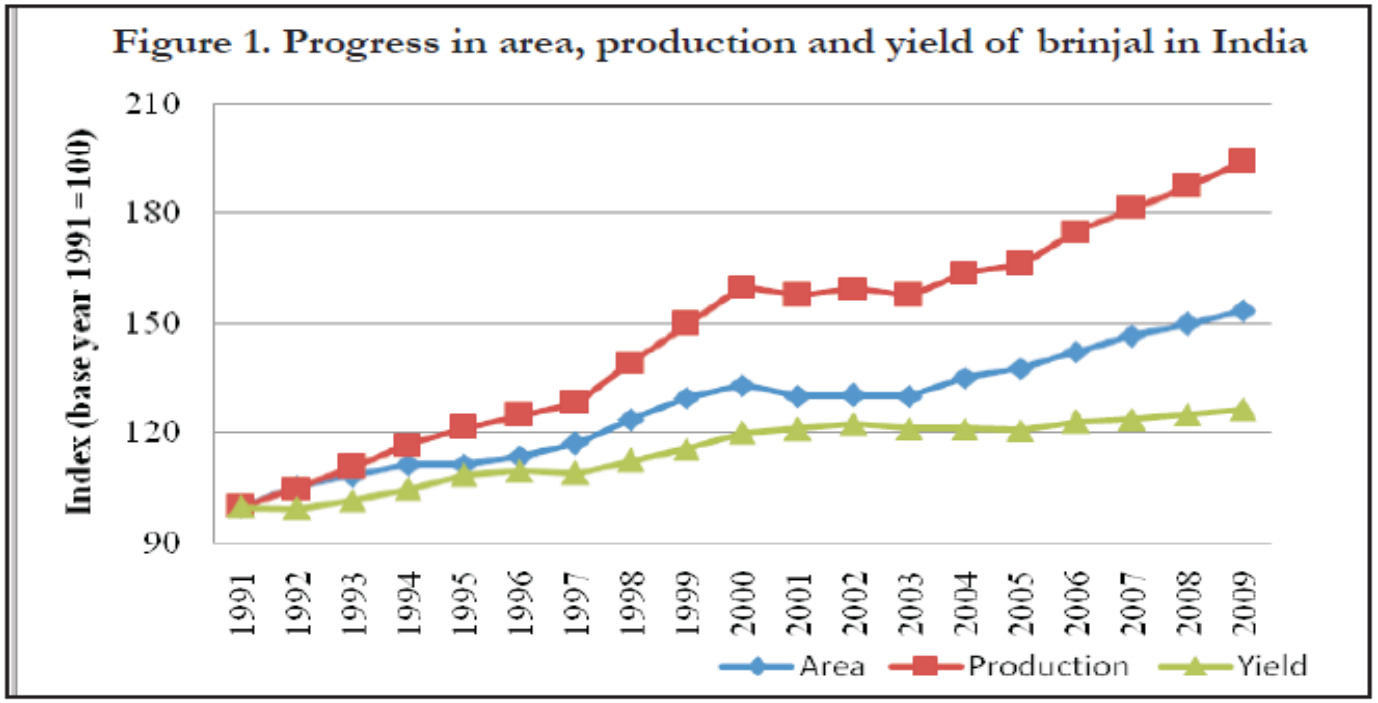
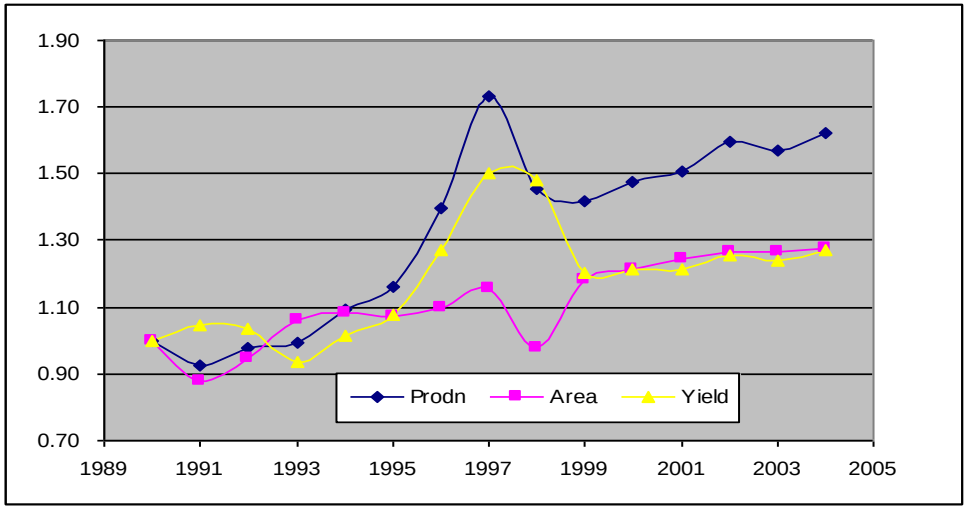
# Trends in Production, Area, and Yield in India



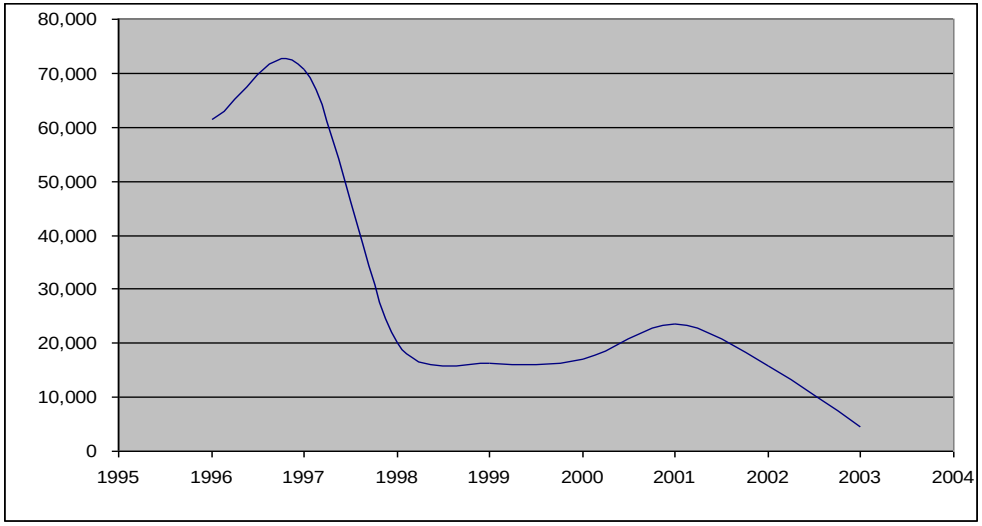

***Increase in production has largely been driven by increase in area***

Source: Kumar et al. 2010. www.ncap.res.in/upload_files/policy_brief/pb34.pdf

# Trends in Production, Area, Yield and Profitability in the Philippines




Increasing production brought about by increase in area and yield




***declining profitability …***

Slide Source: Dr. S. Francisco

# FSB and the injuries it causes

**Eggplant Fruit and Shoot Borer (FSB) (*Leucinodes orbonalis* Guenee)**



Photo courtesy of Rao, 2010

**most destructive insect pest of eggplant (60-70% yield loss)**

**Shoot damage**

**Stem damage**

**Exterior fruit damage**

**Fruit flesh damage**

# Rationale for developing Bt eggplant

- Significant yield loss due to insect damage
- Excessive use of pesticides and potential harm to human health and environment
- Higher cost of production due to pesticides
- No effective resistance in conventional varieties

# Spraying Practices to Control FSB

- **Bangladesh** - more than 140 times during a cropping season of 180-200 days (Rashid et al, 2003)
- **Philippines** - up to 80 times per cropping season (Quicoy, 2010)
- **India** – up to 35 times each growing season (Kolady and Lesser, 2008)
- *"The number of spray operations per week has been proven to have significant association with the likelihood of experiencing neurobehavioral, respiratory & intestinal symptoms in a study among Indonesian farmers."- Kishi et al., 1995*

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# Insecticides used to control FSB

- Organophosphates
- Pyrethroids
- Carbamates

*Table 5. Types of insecticides used against EFSB in Jessore District, July 2000 to February 2001*

| Chemical | Trade name[1] | Farmers using (%) | Quantity a.i. used per spray[2] (g or ml/ha) | Recomm. dose of a.i. per spray[2] (g or ml/ha) | Re-entry period (days) |
|---|---|---|---|---|---|
| *Carbamate* | | | | | |
| Carbosulfan | Marshall 20 EC | 50 | 254 | 200 | 15 |
| Cartap | Suntuf 50 SP | 52 | 225 | 400 | 15 |
| *Organophosphate* | | | | | |
| Malathion | Fyfanon 57 EC | 28 | 512 | 684 | 10 |
| Monocrotophos | Azodrin 40 WSC | 14 | 419 | 400 | 15 |
| Quinalphos | Corolux 25 EC | 54 | 300 | 375 | 15 |
| Quinalphos | Ekalux 25 EC | 48 | 300 | 375 | 15 |
| *Pyrethroid* | | | | | |
| Cypermethrin | Basuthrin 10 EC | 24 | 124 | 100 | 10 |
| Cypermethrin | Ostad 10 EC | 40 | 136 | 100 | 10 |
| Esfenvalerate | Fenfen 20 EC | 14 | 240 | 100 | 10 |

[a]EC = emulsifiable concentrate, SP = soluble powder, WSC = water-soluble concentrate

[2]a.i. = active ingredient

Note: Among the chemicals, only cypermethrin formulations Ostad 10 EC and Basuthrin 10 EC have been registered against EFSB. Other registered insecticides against EFSB are cypermethrin (Fanom 10 EC), cyfluthrin (Baythroid 50 EC), deltamethrin (Decis 2.5 EC), diazinon (Diazinon 60 EC), fenitrothion (Sumithion 50 EC, Agrothion 50 EC, Folithion 50 EC), esfenvalerate (Sumialfa 5 FL), pirimicarb (Pirimor 50 DF) (Source: Plant Protection Wing, 1999).

Source: Rashid et al, 2003. AVRDC Technical Bulletin No. 29
www.avrdc.org/publications/technical_bulletin/TB29.pdf

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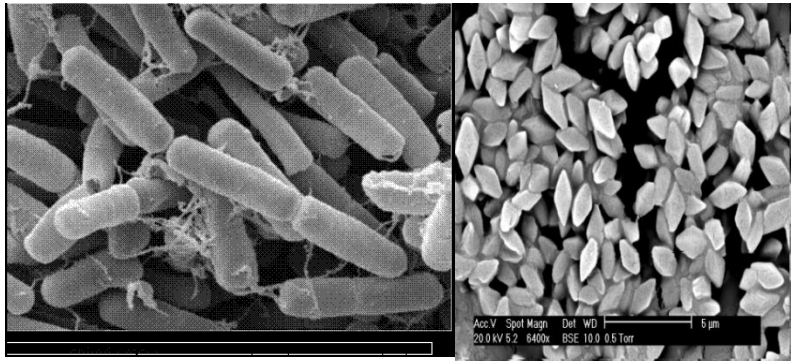
# Bt Eggplant

A novel alternative solution to control FSB

# Bt eggplant technology is based on a naturally occuring bacterium

- *Bacillus thuringiensis*
  - Naturally-occurring soil bacteria
  - Non-pathogenic
- Produces crystal (Cry) insect control proteins with specific target range
  - e.g. Cry1Ac, Cry1Ab
- History of safe use
  - >50 years as biopesticide for insect control in organic and non-organic farms (e.g. DiPel DF)
  - >16 years for insect control as GM crops (Bt cotton; Bt corn)

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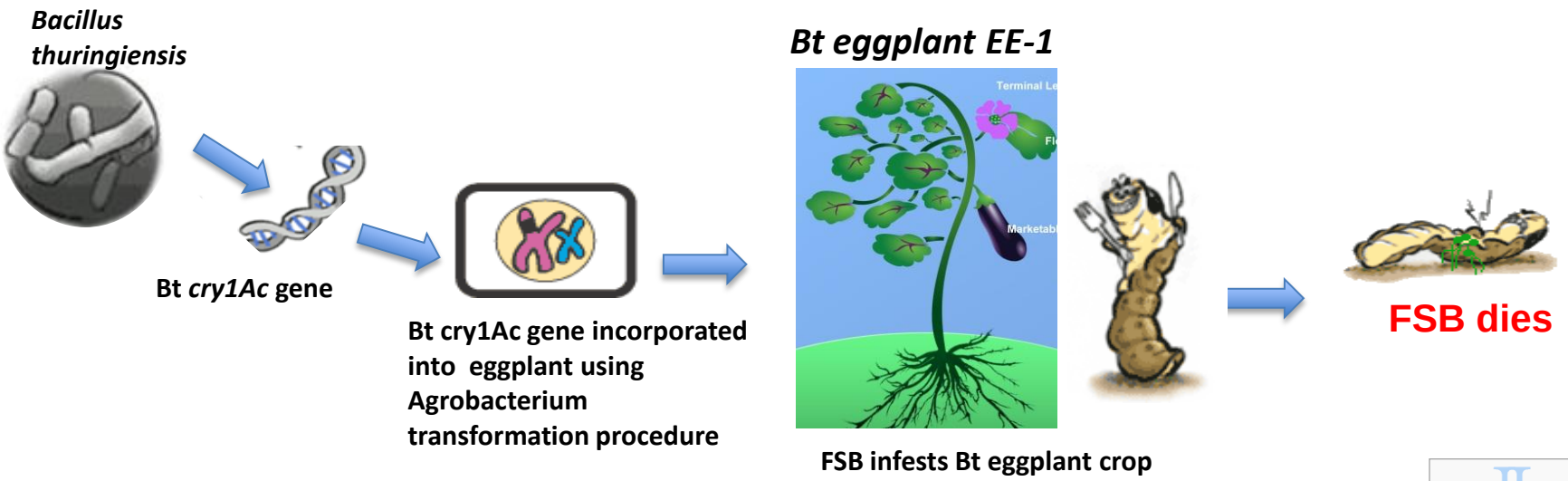
# Bt eggplant donor line from India: *Event EE-1*

Eggplant elite line + *Bt* Cry1Ac → Bt eggplant EE-1




Image/Photo Sources: www.ag.ndsu.edu; www.scq.ubc.ca;

# Bt eggplant EE-1 Safety Studies in India….

| | |
|---|---|
| 2000 | Eggplant transformation initiated |
| 2001 | Greenhouse evaluation |
| 2002 | Pollen flow studies - 2 locations, Backcrossing program initiated |
| 2003 | Acute oral toxicity studies in rats |
| 2004 | Mucous membrane irritation test in female rabbit, Primary skin irritation test in rabbit |
| | Effects on non target and beneficial insects |
| 2005 | Sub chronic oral toxicity study in Spraue Dawley rats |
| | Assessment of allergenicity of protein extracts using Brown Norway rats |
| | Responses, as a dietary feed requirement to common carp growth performances |

# Bt eggplant EE-1 Safety Studies in India (continued)

| | |
|---|---|
| 2006 | Chemical finger printing of Bt and non Bt eggplant (including alkaloids) |
| | Subchronic (90 days) feeding studies using New Zealand rabbit |
| | Effect on performance and health of broiler chickens (Central Avian Izatnagar) |
| | Subchronic (90 days) feeding studies in goats, Feedng studies in lactating crossbred dairy cows, Socio economic and risk assessment |
| 2007 | Pollen flow studies - 2 locations |
| 2008 | Pollen flow studies - 2 locations, |
| Other studies | •Germination and weediness studies,<br>•Aggressiveness studies, Soil micro biota studies ( 3 years),<br>•Substantial equivalence studies, Protein expression studies,<br>•Baseline susceptibility studies (2 years with 29 populations),<br>•Food cooking and protein estimation in cooked fruits,<br>•Molecular characterization and ID |

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# Development of Bt eggplants by ABSPII Partners

- MAHYCO developed Bt eggplant elite line EE-1, which was used as a the common transformation event among ABSPII partners

- Transfer of Bt event EE-1 was done through marker-assisted conventional backcrossing scheme
  - Bt Eggplant event EE-1, as donor parent was crossed with selected lines from India, Bangladesh and Philippines as recurrent parents to develop products for each region and market segment.

- ABSPII supports the regulatory approval of the common event EE-1 and development & commercialization of products by public sector partners

# Bt eggplant Product Development and Regulatory Status

| | INDIA | BANGLADESH | PHILIPPINES |
|---|---|---|---|
| **Contained Trial** | **Completed**<br>Mahyco (2000-2002)<br>Public partners (2003-2004) | **Completed**<br>2005- 2008<br>initial crosses, importation, backcrossing & selection | **Completed**<br>2003-2007<br>initial crosses, importation, backcrossing & selection |
| **Confined Field Trial** | **Completed**<br>Mahyco (2002-2004)<br>Start regulatory dossier | | **Completed**<br>2007-2008 (19 lines, single location trial) |
| **Multi-location Field Trials** | **Completed** (2009)<br>Hybrid – LST (2009)<br>TNAU-OPV (2008_<br>UAS – OPV (2009) | **On –going**<br>2009-present<br>9 OPVs, 7 locations | **On-going**<br>2010-present<br>3 OPVs, 4 hybrids, 4 locations |
| **Safety Assessment and Approval** | **Completed**<br>2009<br>Biosafety approved by GEAC | **For submission** in 2012 | **For submission** in 2012 |
| **Market Release** | **Pending** | | |

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# Bt eggplants Developed by ABSPII Partners in South Asia

Non-Bt Bt

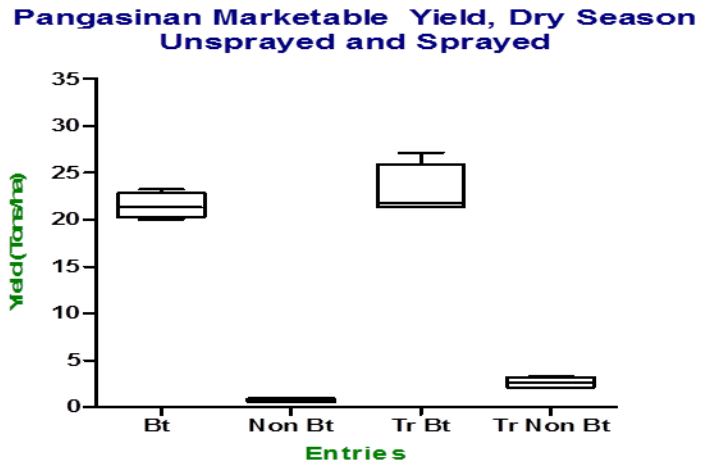
Bt Non-Bt

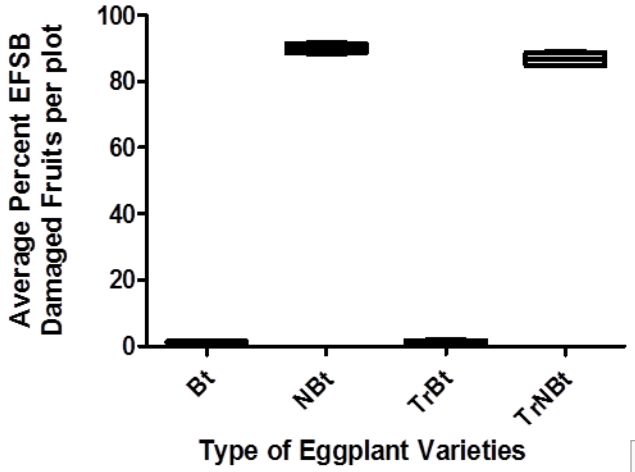
Non-Bt Bt

# Bt eggplant developed by ABSPII Partner in the Philippines- Results of Field Trial

**Without FSB insecticide spray**

**With FSB insecticide spray**



# Potential Socioeconomic Impacts

- Yield gain and reduction in insecticide use
- Benefits to producers and consumers
- Reduce health hazards and environmental pollution

# Data sources and Methodology

- Primary data: elicit information, expert opinion from scientists, industry experts, farmer focus group discussions
- Survey of eggplant farmers
- Secondary data (area, production, yield, prices, cost & returns, publications, FIES)
- Bt trial plot data
- Net cash Income
- Regression analysis
- Economic Surplus Method (Alston et al, 1995; Norton and Davis, 1981)

# Potential Socio Economic Benefits - India

## ABSP II estimates

- 45% reduction in the number of insecticide sprays,
- 117% increase in yield with implications for more affordable vegetables;
- Significant reduction in production costs;
- Positive implications for health, and environment
- Estimated US$411 million per annum increase in net benefits to Indian eggplant farmers and consumers at the national level (ABSP II, 2007; James, 2007)

**Bt is a supply shifting technology and would *induce the price of eggplant to drop with increasing adoption rate through effective transfer* of technology and dissemination of facts and figures thereby benefiting both producers and consumers.**

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# Socio Economic Studies – India

**Book published on: Economic and Environmental Benefits and Costs of Transgenic Crops; Ex-Ante Assessment. TNAU, Coimbatore, Tamil Nadu**

- The study concludes that
  - Insecticide usage reduced by 75%
  - Yield advantages –
    - ~40% for Bt eggplant hybrids vs conventional hybrids;
    - ~60% for Bt hybrids vs conventional OPVs
  - Net income increase –
    - Rs. 16,299/acre in Central/South;
    - Rs. 19,744/acre and East India
  - Adoption rates for Bt technology –
    - 78% in the Center/South
    - 93% in the East

# On-farm pesticide use and potential savings in pesticide expenses due to Bt eggplant - India

| Category | Current | | | Optimum (L/ha) | Savings due to Bt ($/ha)* |
|---|---|---|---|---|---|
| | Sprayings (#) | Use (L/ha) | Expenses ($/ha) | | |
| Hybrid | 35.5 | 71 | 668 | 16.1 | 343 |
| OPV | 12.3 | 27 | 264 | 4.94 | 140 |

*** Estimates based on 52% decrease in pesticide use**

Results suggest that Bt technology provides a good alternative to pesticide use

Slide Source: Kolady, D.

Publication: Kolady D. and Lesser W. 2008. Is genetically engineered technology a good alternative to pesticide use: the case of GE eggplant in India. International J Biotech. 10:132-147

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# Yield gain and reduction in pesticide use due to Bt eggplant - India

| Year | Reduction in insecticide use* (%) | | Increase in marketable fruit yield (%) over | |
|---|---|---|---|---|
| | Against FSB | Against all insect pests | Hybrids used to develop Bt | Popular hybrids |
| 2007-08 | 80.0 | 40.4 | 32.1 | 51.6 |
| 2008-09 | 74.5 | 43.2 | 45.2 | 58.9 |
| Average | 77.2 | 41.8 | 37.3 | 54.9 |

*Note*: *relates to the years 2004-05 and 2005-06

*Source*: IIVR (2009), and AICVIP/ ICAR (2007)

Source: Kumar et al, 2010. www.ncap.res.in/upload_files/policy_brief/pb34.pdf

# Potential economic benefits to farmers and consumers - India

| Particulars | Scenarios: Adoption level | | |
|---|---|---|---|
| | Low (15%) | Medium (30%) | High (60%) |
| **Benefits to farmers** | | | |
| (i) Increase in production ('000 tonnes) | 29.70 | 59.40 | 118.80 |
| (ii) Saving from insecticides for FSB (in crore Rs) | 46.80 | 93.60 | 187.20 |
| (iii) Increase in net returns (in crore Rs) | 623.15 | 1246.30 | 2492.60 |
| **Benefits to consumers** | | | |
| (i) Likely reduction in price (%) | 3.00 | 7.00 | 15.00 |

Source: Kumar et al, 2010. www.ncap.res.in/upload_files/policy_brief/pb34.pdf

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# Socio Economic Impacts - Bangladesh

- Field Trial results indicate
  - Sizeable yield increase in Bt eggplant plots
  - Pest force of FSB significantly reduced in Bt plots
  - Average shoot damage as well as fruit infestation in Bt hybrids far lower than in non Bt eggplant

- TNAU Ex- Ante Study estimates
  - Yield of Bt eggplant is expected to increase by 15-30%
  - Pesticide cost will decrease by 70 – 90%
  - Reduce Pesticide Labour Costs by 70 – 75%
  - Probability of Success – 70 – 90%
  - Yield increase by 15 – 30%
  - Gross Return increase by 37 – 64%

Source: Book published on Economic and Environmental Benefits and Costs of Transgenic Crops; Ex-Ante Assessment. TNAU, Coimbatore, Tamil Nadu

# Potential Socioeconomic Impacts in the Philippines

- **Positive returns to farmers and producers**

  **>200 % increase in farm income**

  - **P50,000 additional per hectare of production**

- **Positive impact on reducing poverty among farmer-adopters and improving the nutritional status of the eggplant consumers**

  - **net impact to poverty was a decrease in the number of poor farmers in eggplant farming households**

- **Significant aggregate benefits for human health, farm animals, beneficial insects, and avian species**

***Source: Francisco, 2007; Francisco et al. 2009a, 2009b, Aragon, 2009***

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# Projected changes in cost and yield, with and without Bt eggplant - Philippines

| Particular | w/o *Bt* *(in PhP)* | with *Bt* *(in PhP)* | Change | |
|---|---|---|---|---|
| | | | Qty (in PhP) | % |
| Pesticides | 16,058 | 7,226 | (8,832) | -55% |
| Pesticide labor cost | 8,545 | 3,418 | (5,127) | -60% |
| Total prod'n cost | 77,258 | 64,634 | (12,624) | -16% |
| Yield (kg) | 8,630 | 12,082 | 3,452 | 40% |
| Gross revenue | 92,945 | 130,123 | 37,178 | 40% |
| Net Income | 15,687 | 65,489 | 49,802 | 317% |

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# Projected health and environmental benefits of *Bt* eggplant - Philippines

| Impact category | % risk avoided | WTP | Benefits (PhP per farmer) | Projected benefits* (PhP) |
|---|---|---|---|---|
| Human health | 19.02% | 1,019.15 | 193.84 | 2,492,229 |
| Farm animals | 19.02% | 867.25 | 164.95 | 2,120,786 |
| Beneficial insects | 21.37% | 893.69 | 190.94 | 2,454,943 |
| Avian Species | 18.67% | 945.25 | 176.51 | 2,269,414 |

* assumed adoption rate of 50% of total eggplant area and farm area = 0.7 has.

***Sources: Francisco, 2007; Francisco et al. 2009a, 2009b, Aragon, 2009***

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# Projected reduction in environmental footprint from changes in pesticide use associated with adoption of Bt eggplant -Philippines

| Particular | without *Bt* eggplant | With *Bt* eggplant | Difference |
|---|---|---|---|
| Pesticide use (kg a.i./ha) | 11.98 | 6.22 | 5.76 |
| Field EIQ | 245.59 | 197.75 | 47.84 |
| % change in pesticide use | | | 48.08% |
| % change in EIQ footprint | | | 19.48% |

***Source: Francisco, 2007; Francisco et al. 2009a, 2009b, Aragon, 2009***

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# Impact of delay in Commercialization - Philippines

| Scenario | Total Surplus (MUSD) | Economic Benefit (MUSD) | NPV of Econ Benefit (MUSD) |
|---|---|---|---|
| Base | 60.47 | 59.94 | 33.90 |
| One year delay | 52.96 (-12%) | 52.44 (-13%) | 28.97 (-15%) |

***Source: Francisco, 2007; Francisco et al. 2009a, 2009b, Aragon, 2009***

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# Concluding Statements

***Bt eggplant adoption is a win-win technology…***

- Bt eggplant is a potentially safer alternative to current pesticide-dependent eggplant production.

- Bt eggplant offers substantial socioeconomic benefits to farmers, consumers and the society at large – *increased income to producers; increased supply, reduced cost, and safer product; reduced health hazard and environmental pollution*

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