IMPACT EVALUATION OF EVENT 'EE-1'- DERIVED EGGPLANT HYBRIDS (*Solanum melongena* L.) CULTIVATION ON PEST MANAGEMENT AND ECONOMIC SUSTAINABILITY

Ronel D. Roberto, Lourdes D. Taylo*, and Desiree M. Hautea

Institute of Plant Breeding, College of Agriculture and Food Science, University of the Philippines Los Baños, College. 4031 Laguna Philippines
*Corresponding author: ldtaylo@up.edu.ph

ABSTRACT

The infestation of eggplant fruit and shoot borer (EFSB), (*Leucinodes orbonalis* (Guenee)) in eggplant (*Solanum melongena* L.) production can lead to yield losses of up to 80%. Farmers rely heavily on insecticide as a means of control and apply different chemistries 70-80 times throughout the cropping season. This practice is expensive and poses risks to farmers, consumers, and the environment. This study addresses these challenges by assessing the impact of the cultivation of UPLB *Bacillus thuringiensis* (Bt) eggplant, the first public-developed genetically engineered vegetable in the Philippines with high resistance against EFSB. This is considered the largest planting of Bt eggplant since its field trials in 2012. A comparative analysis between commercial variety and two Bt eggplant hybrids was performed to determine its efficacy, yield performance, and cost and return analysis in both sprayed and unsprayed with EFSB-specific insecticide conditions. Least Significant Difference (LSD) tests detected significantly higher efficacy, marketable yield, net returns, and cost-benefit ratio of Bt eggplant compared to commercial check hybrid. Meanwhile, no significant differences were found between the two Bt eggplant hybrids. Bt eggplant hybrids without EFSB-insecticide spray demonstrated 0.00% EFSB-damaged shoots, less than 1% EFSB-damage in fruits, and a 200% yield advantage in contrast to commercial check hybrid treated with insecticide spray. The increase in marketable fruits and substantial reduction in insecticide cost and associated labor translated to a higher economic gain. The results highlight the potential of Bt eggplant in enhancing economic sustainability while mitigating the risks associated with the dependency of farmers on insecticides.

Keywords: Bt eggplant**,** genetic engineering, eggplant fruit and shoot borer, efficacy, biotechnology

INTRODUCTION

Eggplant, also known as brinjal in South Asia or aubergine in Europe, is a widely cultivated vegetable in the Philippines. At the national level, it is considered one of the most important but inexpensive and popular vegetables. In 2022, eggplant was planted on 21,960 hectares, producing 248,150 metric tons valued at Php 9.22 billion (PSA 2022).

Eggplant is susceptible to feeding damage from arthropod pests and infection from plant diseases. Among the insect pests, the eggplant fruit and shoot borer (EFSB) is the most chronic and damaging, with losses reaching up to 80% (Francisco 2009). The larval stage of the EFSB is the most damaging because the larva burrows inside the shoot or fruit where it is protected from most insecticides. Borers also feed on eggplant flowers, but the most severe damage is to the fruits, making them unmarketable.

Farmers have long been practicing Integrated Pest Management (IPM), which includes a combination of non-pesticide-based control strategies. However, farmers have been overly dependent on insecticides, using various mixes. Insecticides account for about 40% of eggplant production costs. However, once EFSB larvae tunnel into the tissue, they are unaffected by the insecticide and continue growing inside the tissue until they reach the last larval stage and exit the tissue as pupae.

Alternative strategies are needed because of the severe negative effects of insecticides on human health and the environment, ineffectiveness, and high cost(Brookes 2022). Traditional breeding efforts have not produced eggplant lines with commercially high resistance to EFSB, so collaborative efforts between Maharashtra Hybrid Seeds Co. Pvt. Ltd (Mahyco) and partner state universities and research institutions in India, the Philippines, and Bangladesh were established to develop their own Bt eggplant lines using Mahyco’s Event EE-1 through a royalty-free sublicensing agreement. The Sathguru Management Consultants Pvt. Ltd. brokered the agreement through USAID-funded projects based at Cornell University-The Agriculture Biotechnology Support Project II, Feed the Future Eggplant Improvement Project, and the Feed the Future-Insect Resistant Eggplant Partnership. The local funding agency, the Department of Agriculture-Biotechnology Program Office, also provided significant research funds for the project's continuity.

As a genetically engineered crop, Bt eggplant underwent rigid risk assessments during each regulatory stage. Several regulatory stages were conducted: a contained trial (2007 to 2008) and a limited confined field trial (2008 to 2009) under the Department of Science and Technology-Biosafety Committee. From 2010 to 2012, multi-location field trials were conducted in Pangasinan, Laguna, Camarines Sur, and North Cotabato under the Department of Agriculture-Bureau of Plant Industry, with the DA Administrative Order No. 8, s. 2002. Then, the Application for Food, Feed Processing with the Joint Department Circular (JDC) 1, s. 2016 followed. The biosafety permit for food, feed, or processing was obtained on July 21, 2021, confirming that Bt eggplant is as safe as its non-Bt counterpart. It took almost two decades before the Bt eggplant project was approved for commercial cultivation on October 18, 2022 (Bugnosen 2022). Parallel with the biosafety permits for cultivation, an Insect Resistance Management (IRM) plan was submitted to delay the development of resistance by EFSB to the Bt protein expressed in the plants and prolong the durability of the Bt technology. Event 'EE-1' was also registered as a Plant Incorporated Protectant-Insecticide to the DA-Fertilizer and Pesticide Authority and UPLB as a licensed pesticide handler.

Currently, the Philippines is only the second country in the world to approve cultivation of Bt eggplant, next to Bangladesh in 2014 (Hayes 2023). With the granting of the biosafety permit for cultivation of UPLB Bt eggplant, UPLB established the first field planting (farm-scale size) of Bt eggplant from December to May 2024. This study was done to assess the comparative field performance of the two Bt eggplant hybrids and commercial check variety against EFSB in unsprayed and sprayed with EFSB insecticides, and determine the economic viability of Bt eggplant cultivation.

MATERIALS AND METHODS

Test Materials

Two (2) UPLB-developed Bt eggplant hybrids, namely Bt Talong 'EE-1' Hyb-1 and Bt Talong 'EE-1' Hyb-2, and a widely utilized commercial hybrid check, were used in the study.

Site and Duration of the Study

The one-season farm-scale performance evaluation of the two UPLB Bt eggplant hybrids compared to a commercial check variety was established in Lots UO4 and UX2 IRRI upland experimental station at Brgy. Paciano Rizal, Los

Baños, Laguna, with geographic coordinates 14°08'39.56"N, 121°15'49.48"E to 14°08'42.34"N, 121°15'47.12"E from November 2023 to May 2024 (**Figure 1**).

Experimental Layout and Design

The field experiment followed a split plot two-factor design, with and without EFSB-specific insecticide as the main plots and varieties (two Bt eggplant hybrids and one commercial check) as subplots in a randomized complete block design with five replications (**Figure 2**). Each replicate covered 0.2 hectares, totaling 1 hectare for five replications. The 0.33 hectare allotted for each hybrid constituted the biggest planting of Bt eggplant in a single location since its field trials in 2012. Rows measuring 30m long and 1.2m wide were prepared thoroughly, and 37 seedlings were transplanted at 0.8m between hills. For each 9-row Bt eggplant hybrid plot, 18 non-Bt isogenic hybrid comparators were transplanted as refuge in both ends.

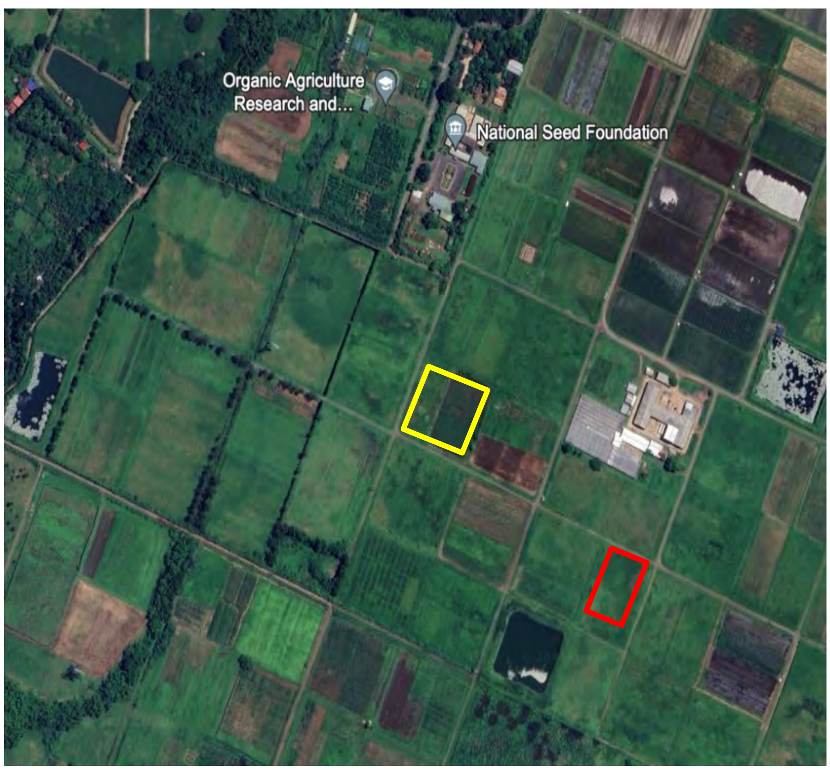

Figure 1. Satellite map of the location of the farm-scale performance evaluation of IPB-UPLB Bt eggplant hybrids at Lot UO (Yellow) and Lot UX (Red) in IRRI/UPLB Upland Experimental Station. (Source: Google Earth satellite image 2024).

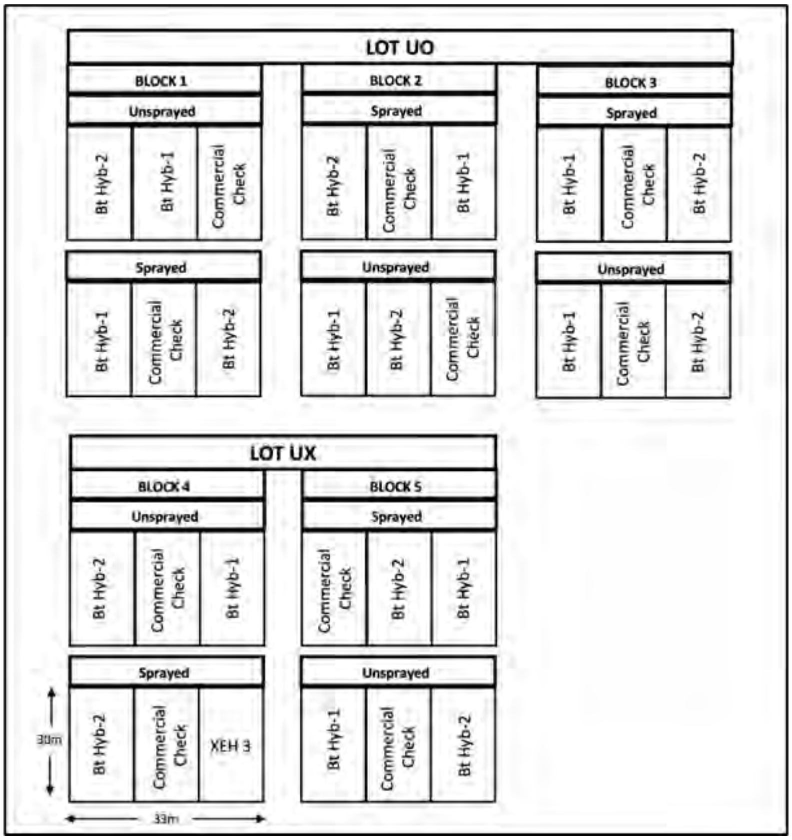

Figure 2. Experimental layout of the farm-level performance evaluation of Bt eggplant hybrids from December 2023 to May 2024 at Lot UO and UX in IRRI/UPLB Upland Experimental Station.

Crop Establishment

Seeds were sown in 72-hole plastic seedling trays and were maintained inside the IPB BL2 Screenhouse. A polymerase chain reaction (PCR) test using an event-specific primer was performed to confirm the presence of the Bt *cry1Ac* gene in the Bt eggplant hybrids.

Watering was done lightly on the plants one week before transplanting to harden the roots of the transplants. Basal fertilizer application, which consisted of complete fertilizer and organic compost, was done. All cultural management practices were based on the national cooperative testing guidelines for eggplant and the recommended practices by the eggplant farmers from Sta. Maria, Pangasinan and Tiaong, Quezon. These farmers are the target beneficiaries once the Bt eggplant deployment commences.

Insecticide Spray Schedule for Sucking Insects and EFSB

FPA-approved and recommended EFSB-specific insecticides (a.i., chlorantraniliprole, spinetoram, and fipronil) were applied to sprayed blocks at weekly intervals (FPA 2024). Sucking insects such as leafhoppers, thrips, and whiteflies were managed by implementing an insecticide spray schedule based on the observed abundance threshold levels (**Table 1**). The decision for spraying was made through regular observations and field monitoring of pest populations.

Table 1. Insecticide spray schedule for sucking insects.

Weeks After Transplanting	Growth Stage	Active Ingredient	Target Pest
4	Vegetative	Thiamethoxam	Aphids, Leafhopper
6	Flowering	Lambdacyhalothrin + Thiametoxam	Whiteflies, green leafhoppers, aphids
8	Flowering	Lambdacyhalothrin; Abamectin	Cutworms, Leafhoppers, Thrips, Aphids
9	Fruiting	Chlorfenapyr	Aphids, Thrips
11	Fruiting	Lambdacyhalothrin	Cutworm, Thrips, Aphids
12	Fruiting	Lambdacyhalothrin	Cutworm, Thrips, Aphids
13	Fruiting	Chlorfenapyr	Aphids, Thrips
15	Fruiting	Lambdacyhalothrin + Thiametoxam	Whiteflies, green leafhoppers, aphids
16	Fruiting	Dinotefuran	Hoppers, Whiteflies

Data Gathering and Analysis

Evaluation of EFSB damage. Natural EFSB infestations were employed in the study. The efficacy of Bt eggplant against EFSB was determined by observing damaged shoots, fruits, and larval count. EFSB-damaged shoots were observed among the 34 randomly selected and tagged plants in each block. At 60 DAT, harvesting started, and fruits suspected of EFSB damage per plot were cut open to check the presence of EFSB larvae or EFSB feeding tunnels. The number of EFSB-damaged fruits and surviving larvae per plot were counted and recorded.

Yield performance. Starting at 8 WAT, harvesting was done at four (4) days intervals for two (2) months. Fruits were sorted and weighed either as marketable (straight, with no EFSB damage and no fruit rot disease) or unmarketable (off-size, with EFSB damage, diseased). Yields were extrapolated in tons/ha.

Economic impact. The economic impact of Bt eggplant hybrid cultivation was determined by analyzing the cost-return and benefit-cost ratio compared to the commercial check hybrid, adopted from the paper of Francisco (2014). The production costs consisting of labor, capital, and other inputs were recorded, while gross sales were calculated based on a common market price of eggplant. Partial budget analysis was carried out to determine the total economic benefits of Bt eggplant cultivation.

Statistical analysis. Sequential tests of hypotheses were performed to evaluate significance at a 5% level of significance. Shapiro-Wilk tests were employed to assess the normality of distribution. Since the data are normally distributed, ANOVA was carried out to test interaction effects, main effects, and subplot effects. Least Significant Difference tests were executed to compare treatment means.

RESULTS AND DISCUSSION

Efficacy of Bt Eggplant Against EFSB

The parameters used to evaluate the efficacy of Bt eggplant hybrids in controlling EFSB include % EFSB shoot damage, % EFSB fruit damage, and surviving larvae in fruits. Statistical analysis at a 0.05 significance level revealed highly significant differences among all parameters. Both Bt eggplant hybrids exhibited high efficacy, with a mean of 0.00% EFSB damage observed in shoots, less than 1% EFSB-damaged fruits, and fewer surviving larvae collected in fruits (**Table 2, Table 3,** and **Table 4**). Meanwhile, pairwise mean comparisons detected a highly significant difference in both Bt eggplant hybrids over the commercial hybrid check variety while no significant difference was found between the two Bt eggplant hybrids. Moreover, Bt eggplant hybrids without EFSB-insecticide exhibited significantly low EFSB-caused damages compared to commercial check hybrids sprayed with insecticide against EFSB (**Table 5**).

Table 2. Mean comparison of percentages of EFSB-damaged shoots and fruits and larval counts between Bt eggplant and non-Bt commercial hybrid check without EFSB insecticide spray.

Comparison[1]	% EFSB-Damaged shoots[2]			% EFSB-Damaged Fruits[3]			Larval Count[3]		
	Bt	Comm Hyb Ck	Signif-icance	Bt	Comm Hyb Ck	Signif-icance	Bt	Comm Hyb Ck	Signif-icance
Bt Hyb-1 vs Non- Bt Comm Hyb Ck	0.00	38.43	**	0.44	69.94	**	0.34	87.64	**
Bt Hyb-2 vs Non- Bt Comm Hyb Ck	0.00	38.43	**	0.34	69.94	**	0.30	87.64	**

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; Non-Bt = commercial check hybrid with no GM event
[2]Mean of 10 weekly observations and 5 replications; collected from 34 sample plants
[3]Mean of 5 replications; collected from each plot; 16 harvest periods

Table 3. Mean comparison of percentages of EFSB-damaged shoots and fruits, and larval counts between Bt eggplant and non-Bt commercial hybrid check, with EFSB insecticide spray.

Comparison[1]	% EFSB-Damaged shoots[2]			% EFSB-Damaged Fruits[3]			Larval Count[3]		
	Bt	Comm Hyb Ck	Signif-icance	Bt	Comm Hyb Ck	Signif-icance	Bt	Comm Hyb Ck	Signif-icance
Bt Hyb-1 vs Non- Bt Comm Hyb Ck	0.00	32.06	**	0.62	70.06	**	0.50	95.02	**
Bt Hyb-2 vs Non- Bt Comm Hyb Ck	0.00	32.06	**	0.28	70.06	**	0.34	95.02	**

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; NBt = commercial check hybrid with no GM event
[2]Mean of 10 weekly observations and 5 replications; collected from 34 sample plants
[3]Mean of 16 harvest periods and 5 replications; collected from each plot

Results of ANOVA for split-plot design at 0.5 level of significance revealed no significant effect of spraying on the efficacy of eggplant hybrids against EFSB. Contrastingly, the eggplant hybrids showed highly significant results across all efficacy measures. Moreover, no significant interaction was found between the spraying practices and eggplant hybrids.

The high level of control of Bt eggplant against EFSB is consistent with the results of multilocation trials conducted in 2010-2012 (Hautea et al. 2016). This demonstrates that Bt eggplant is still highly effective and superior in controlling EFSB compared to the conventional check variety on a farm-scale level. Farmers can anticipate an increase in marketable yield due to a few EFSB damages to fruits. Since no significant effect of spraying is found, farmers may no longer need to apply insecticides to control the target insect pest, which will lead to savings on insecticide costs and the associated labor expenses. Bt eggplant proves its position as a valuable alternative technology for farmers striving for sustainable pest management while enhancing economic productivity and profitability.

Table 4. Mean comparison of percentages of EFSB-damaged shoots and fruits and larval counts between Bt eggplant and non-Bt commercial hybrid check, with and without EFSB insecticide spray.

Comparison[1]	% EFSB-Damaged shoots[2]			% EFSB-Damaged Fruits[3]			Larval Count[3]		
	Without spray	With spray	Significance	Without spray	With spray	Significance	Without spray	With spray	Significance
Bt Hyb-1 vs Bt Hyb-1	0.00	0.00	ns	0.44	0.62	ns	0.34	0.50	ns
Bt Hyb-1 vs Comm Hyb Ck	0.00	32.06	**	0.44	70.06	**	0.34	95.02	**
Bt Hyb-2 vs Bt Hyb-2	0.00	0.00	ns	0.34	0.28	ns	0.30	0.34	ns
Bt Hyb-2 vs Comm Hyb Ck	0.00	32.06	**	0.34	70.06	**	0.30	95.02	**
Non-Bt Comm Hyb Ck vs Non-Bt Comm Hyb Ck	38.43	32.06	ns	69.94	70.06	ns	87.64	95.02	ns

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; Non-Bt = commercial check hybrid with no GM event
[2]Mean of 10 weekly observations and 5 replications; collected from 34 sample plants
[3]Mean of 5 replications; collected from each plot; 16 harvest periods

Table 5. The percentage bioefficacy against EFSB of Bt eggplant hybrids compared with non-Bt commercial hybrid check, with and without EFSB insecticide spray.

Comparison[1]	% EFSB-Damaged shoots[2]		% Efficacy[4]	% EFSB-Damaged Fruits[3]		% Efficacy[4]	Larval Count[3]		% Efficacy[4]
	Without spray	With spray		Without spray	With spray		Without spray	With spray	
Bt Hyb-1 vs Non- Bt Comm Hyb Ck	0.00	32.06	100.00	0.44	70.06	99.37	0.34	95.02	99.64
Bt Hyb-2 vs Non- Bt Comm Hyb Ck	0.00	32.06	100.00	0.34	70.06	99.51	0.30	95.02	99.68

[1]Bt = hybrids with the Cry1Ac Bt gene; NBt = commercial check hybrid with no GM event
[2]Mean of 5 replications and 10 weekly observations; collected from 34 sample plant
[3]Mean of 5 replications; collected from each plot; 16 harvest periods
[4]% Efficacy = (1 – Bt/non-Bt) × 100

Yield Performance

The yield performance of Bt eggplant hybrids was compared to the commercial hybrid check variety by assessing the marketable eggplant fruits without EFSB damage at each harvest period. Both Bt eggplant hybrids demonstrated a significantly higher yield of undamaged marketable fruits compared to the commercial non-Bt hybrid check, with no significant differences observed between the two Bt hybrids. Bt Talong 'EE-1' Hyb-1 achieved up to 15.37 tons/ha, while Bt Talong 'EE-1' Hyb-2 reached 16.27 tons/ha even without EFSB sprays or about a 2-fold increase in marketable yield. The EFSB-damaged yield for Bt eggplant was only 0.16 tons/ha, specifically for Bt Talong 'EE-1' Hyb-2. In contrast, the commercial hybrid check produced a marketable yield of around 4.35 tons/ha and had EFSB-damaged fruits totaling up to 8.06 tons/ha despite treating EFSB with insecticides.

ANOVA detected no significant effect ($p > 0.05$) of spraying on the yield performance of the eggplant hybrids. This is evidenced by the high yield of undamaged fruits in Bt eggplant hybrids and the low yield of marketable fruits in the commercial hybrid check variety, regardless of spraying conditions (**Table 6** and **Table 7**). Additionally, there is no significant interaction between the spraying practices and eggplant varieties. The findings highlight the outstanding yield performance of Bt eggplant, which can be attributed to its effective control of EFSB damage. Bt eggplant plots without spray exhibited a significant advantage over the commercial check plots treated with insecticide (**Table 8**). Pairwise mean comparisons also revealed that both eggplant hybrids produced significantly higher yield of marketable fruits and lower EFSB-damaged fruits than commercial hybrids. Remarkably, Bt eggplant hybrids showcased a yield advantage of over 200% (**Table 9**). This suggests that a farmer who cultivates Bt eggplant can expect a significantly higher yield even without resorting to insecticide application compared to those growing conventional eggplant and rely on chemical spraying to combat EFSB. This will be translated into 44% savings in insecticide sprays and a 65% reduction in the associated labor cost in spraying.

Table 6. Yield comparison between Bt eggplant and commercial eggplant hybrids, without EFSB-insecticide spray.

Comparison[1]	Undamaged fruit yield (tons/ha)[2]			EFSB-damaged fruits (tons/ha)[2]		
	Bt	Non-Bt	Significance	Bt	Non-Bt	Significance
Bt Hyb-1 vs Non- Bt Comm Hyb Ck	14.57	4.40	**	0.07	7.28	**
Bt Hyb-2 vs Non- Bt Comm Hyb Ck	13.98	4.40	**	0.16	7.28	**

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; Non-Bt = commercial check hybrid with no GM event
[2]Mean of the extrapolated yield after 16 harvest periods (yield potential in tons per hectare); 5 replicates

Table 7. Yield comparison between Bt eggplant and commercial eggplant hybrids, with EFSB-insecticide spray.

Comparison[1]	Undamaged fruit yield (tons/ha)[2]			EFSB-damaged fruits (tons/ha)[2]		
	Bt	Non-Bt	Significance	Bt	Non-Bt	Significance
Bt Hyb-1 vs Non- Bt Commercial Hyb Ck.	15.37	4.35	**	0.07	8.06	**
Bt Hyb-2 vs Non- Bt Commercial Hyb Ck	16.27	4.35	**	0.02	8.06	**

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; Non-Bt = commercial check hybrid with no GM event
[2]Mean of the extrapolated yield after 16 harvest periods (yield potential in tons per hectare); 5 replicates

Table 8. Yield comparison between Bt eggplant and commercial hybrid check, with and without EFSB-insecticide spray.

Comparison[1]	Undamaged fruit yield (tons/ha)[2]			EFSB-damaged fruits (tons/ha)[2]		
	Without spray	With spray	Significance	Without spray	With spray	Significance
Bt Hyb-1 vs Bt Hyb-1	14.57	15.37	ns	0.07	0.07	ns
Bt Hyb-1 vs Bt Hyb-2	14.57	16.27	ns	0.07	0.02	ns
Bt Hyb-1 vs Non- Bt Comm Hyb Ck	14.57	4.35	**	0.07	8.06	**
Bt Hyb-2 vs Bt Hyb-2	13.98	16.27	ns	0.16	0.02	ns
Bt Hyb-2 vs Bt Hyb-1	13.98	15.37	ns	0.16	0.07	ns
Bt Hyb-2 vs Non- Bt Comm Hyb Ck	13.98	4.35	**	0.16	8.06	**
Non- Bt Commercial Check Hyb. vs Non- Bt Comm Hyb Ck	4.40	4.35	ns	7.28	8.06	ns

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; Non-Bt = commercial check hybrid with no GM event
[2]Mean of the extrapolated yield after 16 harvest periods (yield potential in tons per hectare); 5 replicates

Table 9. Yield advantage of Bt eggplant hybrids compared with commercial hybrid check, with and without EFSB-insecticide spray.

Comparison[1]	Undamaged fruit yield (tons/ha)[2]		Yield advantage (%)[3]
	Without spray	With spray	
Bt Hyb-1 vs Non- Bt Comm Hyb Ck	14.57	4.35	234.94
Bt Hyb-2 vs Non- Bt Comm Hyb Ck	13.98	4.35	221.38

Mean comparison by LSD in STAR; ** highly significant at 1% significance level; mean of 5 replicates
[1]Bt = hybrids with the Cry1Ac Bt gene; NBt = commercial check hybrid with no GM event
[2]Mean of the extrapolated yield after 16 harvest periods (yield potential in tons per hectare); 5 replicates
[3]Yield advantage = ((Undamaged Fruit Yield of Bt – Undamaged Fruit Yield of non-Bt)/(Undamaged Fruit Yield of Non-Bt)) x 100

Cost and Return Analysis

The increase in marketable yield as a result of high efficacy of Bt eggplant hybrids against EFSB, and reduced pesticide use and the associated labor costs, were translated to a higher net income and return on investment. The cost of production in sprayed and no EFSB insecticide spray with and without EFSB sprays was accounted for and compared. Twenty-three spray applications were recorded for a 3.5-month production period. However, this is less than farmers' practice, which suggests up to 80 times spraying frequency for the 6-9 months production period. The results indicated that labor accounts for the highest percentage or 59% of the total production cost with EFSB-insecticide spray, of which 30% is attributed to insecticide spraying (**Figure 3A and 3C**). Meanwhile, insecticides account for 20% of the total cost, equivalent to Php 50,130. The share of insecticide in the total cost is consistent with Francisco's findings in 2014 in Pangasinan. A 65% reduction in labor cost and a 44% reduction in insecticide were recorded in production costs without EFSB insecticide spray (**Figure 3B** and **Figure 3C**). Gross sales were computed using a constant price of Php 44,000/metric ton or Php 44/kilogram (PSA 2023) across hybrids. A net income of more than Php 400,000.00 was obtained for both Bt eggplant hybrids, equivalent to a return of more than 1.54 on investment (**Table 10**). On the other hand, a negative net income and benefit-cost ratio were observed for the commercial hybrid check, primarily due to low marketable yields caused by EFSB infestation. As a result, about Php 60,858.49 loss was incurred. Farmers counteract losses due to EFSB by increasing the frequency of insecticide applications, a harmful and unsustainable practice.

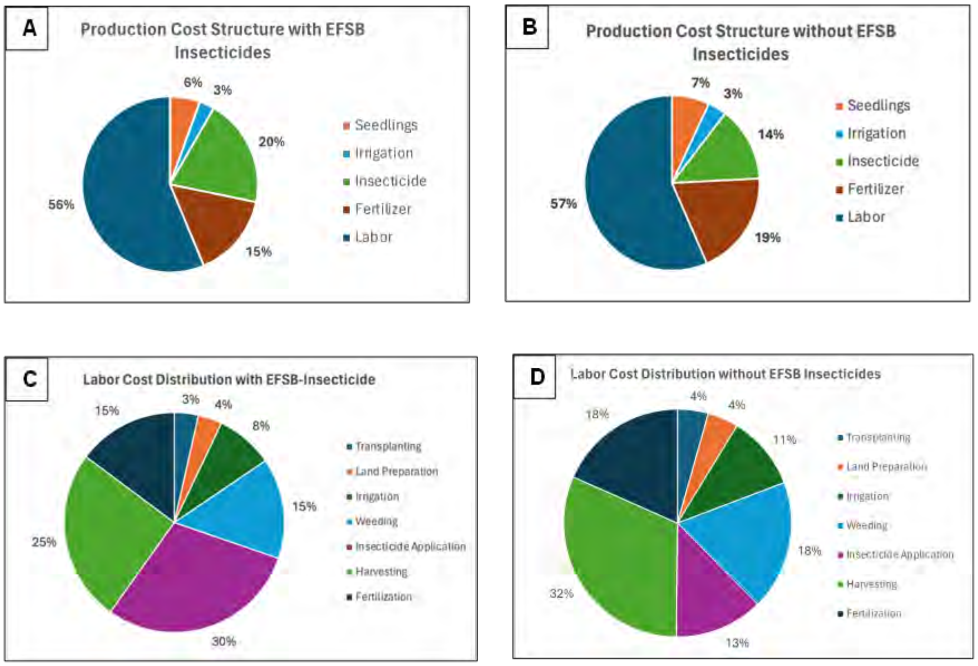

Figure 3. Distribution of production and labor costs, with **(A and C)** and without **(B and D)** EFSB insecticide spray.

Table 10. Cost and return analysis of Bt eggplant and commercial eggplant hybrid production between with and without EFSB-insecticide spray.

Particular	Unsprayed			Sprayed		
	Bt eggplant Hyb-1	Bt eggplant Hyb-2	Comm Hyb Ck	Bt eggplant Hyb-1	Bt eggplant Hyb-2	Comm Hyb Ck
Production						
Marketable yield (metric tons/ha)	14.57	15.37	4.4	13.98	16.27	4.35
Price per metric ton (Php)[1]	44,000	44,000	44,000	44,000	44,000	44,000
Gross sales (Php)	641,172.97	615,360.08	193,805.16	676,125.04	715,756.90	191,341.51
Production Cost						
Seedlings	14,040	14,040	14,040	14,040	14,040	14,040
Labor (land preparation, crop maintenance, harvesting)	114,400	114,400	114,400	142,000	142,000	142,000
Pesticide	27,892	27,892	27,892	50,130	50,130	50,130
Fertilizer	39,030	39,030	39,030	39,030	39,030	39,030
Irrigation	7,000	7,000	7,000	7,000	7,000	7,000
Total Production Cost (Php)	202,362	202,362	202,362	252,200	252,200	252,200
Net Income (Php)	438,810.97	412,998.08	-8,556.84	423,925.04	463,556.90	-60,858.49
Benefit Cost Ratio (B/C)	1.64	1.54	-0.07	1.94	2.12	-0.3

[1]PSA Eggplant Production Value for Q4 2023

Partial Budget Analysis

The total benefits derived from cultivating Bt eggplant hybrids without spray were determined by accounting for the value of increased marketable yield and savings from spraying expenses compared with the commercial check variety with EFSB-insecticide spray. The Bt Talong 'EE-1' Hyb-1 reached a 10.22 tons marketable yield per hectare equivalent to Php 464,200 added returns, while Bt Talong 'EE-1' Hyb-2 had an additional gain of 9.63 tons/ha or about Php 423,720. The reduced cost of production without EFSB-insecticide spray amounted to Php 49,838. The total added benefits of Bt Talong 'EE-1' Hyb-1 and Bt Talong 'EE-1' Hyb-2 were Php 514,038 and Php 473,558, respectively.

Table 11. Partial budget analysis of Bt eggplant hybrids without EFSB-insecticide spray vs. commercial check hybrid with EFSB-insecticide spray.

Particulars	Bt Eggplant[1]	Non-Bt Comm Hyb Ck [2]	Difference
Bt Talong 'EE-1' Hyb-1			
Marketable yield (tons/ha)	14.57	4.35	10.22
Added returns[2]			464, 200
Production cost	202,362	252,200	49,838
Reduced cost			49,838
Total added benefits			514,038
Bt Talong 'EE-1' Hyb-2			
Marketable yield	13.98	4.35	9.63
Added returns			423,720
Production cost	202,362	252,200	49,838
Reduced cost			49,838
Total added benefits			473,558

[1]Bt Eggplant= hybrids with the Cry1Ac Bt gene
[2]Non-Bt Eggplant = commercial check hybrid with no GM event

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The event 'EE-1'- derived Bt eggplant hybrid is the country's first genetically modified vegetable crop by the University of the Philippines Los Baños. The Biosafety Permit for Commercial Propagation (No. 22-001 Propa) of UPLB Bt eggplant was obtained last October 18, 2022, and paved the way for establishing an on-farm demonstration planting. The farm-scale planting of Bt eggplant hybrids, Bt talong 'EE-1' Hyb 1 and Bt talong 'EE-1' Hyb 2 was conducted with and without EFSB-insecticide spray from December 2023 to May 2024 and compared with the commercial hybrid check variety in terms of bioefficacy, yield performance, and cost and return analysis of planting Bt eggplant hybrids.

It constituted the largest field planting of Bt eggplant since its multilocation trial in 2012. It would be ideal if the farm-scale planting were done in Pangasinan, which was historically recorded to have a high EFSB field population, to assess the field performance of UPLB-developed Bt eggplant hybrids.

Field performance of Bt eggplant hybrids showed significantly lower percentages of EFSB shoot and fruit damage and fewer larval counts even without EFSB spray. The EFSB spray did not result in significantly lower percentages of EFSB shoot and fruit damages and fewer larval counts in Bt and non-Bt commercial check varieties. Both Bt eggplant hybrids demonstrated an outstanding yield advantage over the commercial check hybrid. The yield of Bt eggplant hybrids without an EFSB sprayer is significantly higher than that of non-Bt commercial check variety. Since spraying does not significantly affect the efficacy and yield performance of the Bt eggplant hybrids, farmers would no longer need to spend extensively on insecticides and its required labor. Meanwhile, spray applications against sucking insects such as whiteflies and leafhoppers in Bt eggplant hybrids are still necessary so as not to result to plant's stunted growth and eventually death.

The cost and return analysis indicated an overwhelming net income advantage of planting Bt eggplant hybrids. The added benefits from increased marketable yield and savings from spraying expenses can substantially improve farmers' income.

The result of the farm-scale planting of Bt eggplant highlighted the promising potential of Bt eggplant in enhancing economic sustainability while mitigating the risks associated with the dependency of farmers on insecticide, thereby benefiting the farmers, consumers and the environment.

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