Adoption and Socio-Economic Impacts of the Pre-Harvest Disease Management Technology for *Carabao* Mango in the Philippines

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Abstract

This study was conducted to determine the adoption and socio-economic impacts of the pre–harvest disease management project on anthracnose and stem-end rot control and production cost reduction through need-based fungicide spraying and fruit bagging funded by PCAARRD. Results of the survey of 141 mango farm owners, share-holders and mango contractors in various provinces of the Philippines show that 69% of the respondents fully adopted need-based spraying and fruit bagging while 26% adopted either need-based spraying or bagging. The rest of the mango growers totally refrained from using these techniques in their operations since they do not aim to sell their produce on a commercial scale. The project benefited the *Carabao* mango industry in terms of increased yield and reduced post–harvest losses. The benefit-cost analysis showed that the return to R&D investment and mango growers' production costs amounted to more than 100% which is much higher than the opportunity cost of money (12%). For the social impacts, 82% of the full adopters and 86% of partial adopters reported that their level of living improved after the adoption of the technology. The benefits to the industry could still increase if more mango growers adopt the technology. There is a need to further promote the technology in other mango producing areas in the country.

Keywords: *adoption pathway, need-based fungicide spraying, bagging, impact assessment*

Introduction

Philippine *Carabao* mangoes are exported to North America, Europe and the Middle East by air transport to avoid spoilage while in transit. As a result, the high cost of air transport makes the price of Philippine mangoes uncompetitive compared to Latin American mangoes. The Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), through the Science and Technology Anchor Program (STAP) for Mango combined proper pre-harvest disease control measures with post-harvest hot water treatment and controlled atmosphere storage technology to extend the shelf life of mangoes while being shipped via ocean liners to the long haul destinations. This study analyzed the acceptability and effectiveness of the pre-harvest interventions, namely, need-based fungicide spraying and fruit bagging for anthracnose and stem-end rot control. Need-based fungicide spraying refers to spraying of fungicides at specific production stages where fungal control is most needed in order to minimize costs. To improve the effectiveness of this disease management technology, other proper farming practices such as open center canopy and sanitary pruning, fertilization, flush induction and sanitation should be applied.

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Methodology

The Australian Centre for International Agricultural Research (ACIAR)'s framework on impact assessment was adopted in this study. The framework is based on the premise that the outputs from research and development (R&D) investment would deliver the outcome that will in turn determine the impacts of the project. Impact assessment measures how inputs are used to deliver the outputs, the adoption pathway and the outcomes of adoption.

The impact assessment was conducted in the following areas:

Region I – Pangasinan, Ilocos Norte

Region III – Nueva Ecija, Tarlac, Bataan, Zambales

Region IV – Batangas, Rizal

NCR – Makati, Taguig

Region VI – Iloilo, Guimaras Island

Region XI – Davao del Sur, Samal Island

Primary data were gathered through personal interview of 141 mango growers and contractors and key informants which included five project leaders/technology developers, three exporters, and heads of the Offices of the Provincial Agriculturist of the provinces that were part of the study. The features of the technology that helped facilitate its adoption were assessed in terms of relevance, compatibility and ease of adoption. The ratings used for each aspect were as follows:

Relevance: 1 – least; 2 – less; 3 – relevant; 4 – more relevant; 5 – very relevant.

Compatibility: 1 – least compatible; 2 – less compatible; 3 –compatible; 4 – more compatible; and 5 – very compatible.

Ease of adoption: 1 – least; 2 – less; 3 – easy to adopt; 4 – more easy; 5 – very easy.

The decision to fully or partially apply fungicide spraying and fruit bagging was analyzed using Logistic regression. Partial adoption refers to fungicide spraying without bagging. Full adoption means application of fungicide with bagging.

The variables shown below were tested for their effect on the decision to apply fungicide spraying and bagging (full adoption) or to adopt the technology partially (either fungicide or bagging). The type of adoption (Full adoption = 1; Partial adoption = 0) was used as the dependent variable. Variables 5, 6, 7, 9 and 10 are dummy variables while the other independent variables (1, 2, 3, 4 and 8) have discrete values. With regard to variable 9, Level of fruitfly infestation, only Nueva Ecija was identified as an area with a low level of infestation. Other provinces within Region III involved in mango production were known to have high levels of fruitfly problems. Mango-producing provinces within Regions I, IV, VI and XI also have high levels of fruitfly infestation.

Table 1. Overview of variables used

Variable	Unit of Measure	Regression Code
Independent variables		
1. Total number of mango trees	No. of trees	TREES
2. Number of fruit-bearing trees	No. of trees	FBEAR
3. Age of trees	Years	AGETR
4. No. of years as mango grower or contractor	Years	YEAR
5. Access to extension service	Yes = 1; No = 0	EXTN
6. Membership to mango growers association/ in organization	Yes = 1; No = 0	ASS
7. Other sources of income	Yes = 1; No = 0	OTHERY
8. Farmgate price	PhP/Kg	PRICE
9. Level of fruitfly infestation	High = 1; Low = 0	FFLY
10. Flower induction season	Wet = 1; Dry = 0	SEASON
Dependent variable		
Technology adoption	Full = 1; Partial = 0	

Gross margin analysis was used to compare the advantage of full technology adoption (fungicide spraying and bagging) against partial adoption (no bagging) at the farm level. To determine the impact of the disease management technology on supply, the aggregate supply from the study areas was compared to a condition before technology adoption (i.e., without fungicide spraying and bagging, holding other inputs constant).

To analyze the impact of the recommended disease management technologies at the household level, the presence of socially-valued assets was determined. The adopters were asked to estimate changes in household assets and the contribution of mango production (due to the adoption of technology) to the acquisition of such assets. In addition to household assets, the respondents were also asked to identify where they spent their increase in income (due to adoption of technology): children's education; health care and/or other social obligations. Cross-tabulation of the socio-demographic characteristics of household-respondents was done to compare adopters who experienced increase in income after adoption with adopters with no change in income after adoption.

A benefit-cost analysis was conducted to estimate the returns to the investments spent for the research and extension (R & E) of the technology as well as to compare the benefits and total costs (research and extension plus farm level input costs) incurred in the application of the technology.

The discounted value of the annual benefits and costs generated by the program within the period 2002 up to 2012 were used for the BCA using the opportunity cost of money, 12% as discount rate. Benefits were estimated utilizing the volume of added supply of *Carabao* mangoes as a result of adopting the need-based fungicide spraying and fruit bagging. Monetary values were attached to these physical quantities by incorporating the average farmgate price received by the mango growers from the most recent harvest season when they were interviewed. The total variable cost (cost of farm inputs) per year is the variable cost of the annual additional supply.

Results

Description of the Respondents

The mango grower-respondents were classified as adopters and non-adopters of the technology. Adopters are those who used both the need-based fungicide spraying and fruit bagging, or any of these two practices. Non-adopters are those who did not employ the two practices at the time of interview although they may have used the technology in previous mango production seasons. Out of the 141 respondents, 135 (96%) were adopters and only six (4%) were non-adopters. The adopters were further classified into full and partial adopters. Full adopters are those respondents who used both the need-based fungicide spraying and bagging while partial adopters used either spraying only or bagging only. Majority of the adopters from Regions I, III, IV, and VI are full adopters, whereas, majority (71 percent) of adopters from Region XI are partial adopters. For all regions, 73% of the adopters were classified as full adopters.

Relevance, Compatibility and Ease of Adoption

Need-based Fungicide Spraying

High ratings were given by full adopters on relevance, compatibility and ease of adoption of technology with average mean ratings of 4.66, 4.5 and 4.9, respectively (Table 2). The need-based fungicide spraying was considered as highly relevant in Regions III, IV and XI. On the other hand, full adopters from Regions I and VI gave a relatively lower rating on relevance. This could be explained when taken in the context of another pressing problem, i.e., fruitfly infestation. These two regions are also plagued by fruitflies. The respondents have observed that the need-based fungicide spraying is not relevant anymore since it has not addressed the problem of infestation. In terms of compatibility, respondents from Regions III, IV and VI considered that the technology is very compatible while respondents from Regions I and XI considered it as moderately compatible. Across regions, respondents assessed the technology as easy to adopt.

Among partial adopters, Regions I, IV and VI respondents rated the technology as highly relevant with a mean rating of 5 while respondents from Regions III and XI gave it a relatively lower rating of 4 (Table 3). In terms of compatibility, the technology was seen as moderately compatible with mean ratings of 4, 4.5 and 4.63 by respondents in Regions III, I and XI, respectively, while Regions IV and VI gave the highest rating of 5. Respondents from Regions I, IV and VI observed that the technology is easy to adopt with a mean rating of 5, while Regions III and XI rated ease of adoption as 4 and 4.63, respectively.

Table 2. Mean ratings of the need-based fungicide spraying by the full adopters in selected regions, Philippines, 2013

Region	Relevance	Compatibility	Ease of Adoption
I	4.83	4.25	4.83
III	5.00	5.00	4.80
IV	5.00	5.00	5.00
VI	4.45	5.00	4.91
XI	5.00	4.33	5.00
Average	4.66	4.50	4.90

Table 3. Mean ratings of the need-based fungicide spraying by the partial adopters in selected regions, Philippines, 2013

Region	Relevance	Compatibility	Ease of Adoption
I	5.00	4.50	5.00
III	4.00	4.00	4.00
IV	5.00	5.00	5.00
VI	5.00	5.00	5.00
XI	4.13	4.63	4.63
Average	4.46	4.46	4.31

Table 4 shows that contractors from Regions I and IV rated the need-based fungicide spraying as highly relevant (mean rating of 5) whereas those from Regions III and VI gave it a relatively lower rating (4.8 and 4.2, respectively). In terms of compatibility and ease of adoption, Regions I, IV and VI rated the practice as highly compatible and easy to adopt while respondents from Region III gave a relatively lower rating of 4.75 for compatibility and 4.25 for ease of adoption.

Table 4. Mean ratings of the need-based fungicide spraying by the mango contractors in selected regions, Philippines, 2013

Region	Relevance	Compatibility	Ease of Adoption
I	5.00	5.00	5.00
III	4.80	4.75	4.25
IV	5.00	5.00	5.00
VI	4.20	5.00	5.00
Average	4.64	4.90	4.77

Fruit Bagging

High ratings (with mean ratings above 4) for bagging were given by the full adopters on relevance, compatibility and ease of adoption (Table 5). Respondents from Regions III and IV consider it as highly relevant while a relatively lower rating was given by Regions I, VI and XI respondents. Bagging was seen as highly compatible, rated 5 (by respondents from Regions III, IV and VI) and moderately compatible by respondents from Regions I and XI. In terms of ease of adoption, bagging was observed as very easy to adopt by the respondents from Region IV and relatively easy to adopt by the respondents from the rest of the regions. The relatively lower rating given by respondents from Regions I, VI and XI can be attributed to the fact that there are baggers available in these regions and they are very much familiar with the technology. Thus, they see bagging as a normal pre-harvest activity. In other regions, baggers are not readily available. They have to source baggers from other provinces. Region IV adopters of bagging considered bagging as a highly relevant technology, very compatible and easy to adopt with a mean rating of 5.0, which is the highest rating.

Table 5. Mean ratings of fruit bagging by the full adopters in selected regions, Philippines, 2013

Region	Relevance	Compatibility	Ease of Adoption
I	4.60	4.00	3.80
III	5.00	5.00	4.80
IV	5.00	5.00	5.00
VI	4.78	5.00	4.30
XI	4.00	3.50	3.00
Average	4.75	4.56	4.22

Mango contractors from Regions I, IV and VI considered bagging as highly relevant, very compatible and easy to adopt with a mean rating of 5.0 (Table 6). Respondents from Region III gave a relatively lower rating of 4.0 for relevance, 4.33 for compatibility and 3.67 for ease of adoption.

Table 6. Mean ratings of fruit bagging by the mango contractors in selected regions, Philippines, 2013

Region	Relevance	Compatibility	Ease of Adoption
I	5.00	5.00	5.00
III	4.00	4.33	3.67
IV	5.00	5.00	5.00
VI	5.00	5.00	5.00
Average	4.73	4.78	4.64

Factors Affecting the Adopters' Decision

Logistic regression was used in analyzing the factors affecting the decision to apply fungicide spraying and bagging (full adoption) or to adopt the technology partially (either fungicide or bagging). A total of 81 observations were used in the regression analysis. This involved 59 (72.8%) respondents classified as full adopters and the remaining 22 (27.2%) as partial adopters. Table 7 shows the results of the regression analysis.

Table 7. Logit regression results on the factors affecting adoption

Item	Coefficient	Standard Error	Z	P	Odds Ratio
Constant	-2.3650	1.3960	-1.6940	0.0903	
Year	0.0039	0.0288	0.1346	0.8929	1.0039
Trees	0.0001	0.0010	0.1045	0.9168	1.0001
Fbear	-0.0001	0.0014	-0.0452	0.9639	0.9999
AGETr	0.0278	0.0100	2.7680	0.0056	1.0282
Price	0.0336	0.0220	1.5260	0.1269	1.0342
OtherY_1	1.2310	0.6488	1.8980	0.0577	3.4260
Extn_1	0.9338	0.6315	1.4790	0.1392	2.5440
Ass_1	0.3537	0.6644	0.5323	0.5945	1.4240
Season_1	-0.1540	0.7022	-0.2194	0.8264	0.8572
Ffly_1	-0.4889	1.1310	-0.4322	0.6656	0.6133
Pseudo $R^2 = 0.219$				LR p value = 0.0229	

Results of the regression analysis show that only two variables have significant effects on adoption. Age of trees (AGETr) was statistically significant at $\alpha = 0.01$ while other sources of income (OtherY) was statistically significant at $\alpha = 0.10$ ($p = 0.0577$). The remaining variables did not prove to be significant factors in explaining the choice on full or partial adoption. With two of the variables showing statistical significance, a Likelihood Ratio p value of 0.0229 was obtained. P values less than 0.05 indicate that the regression model has a good predictive power. The Pseudo R^2 has a value of 0.219.

The Odds Ratio indicates that for every unit increase in the independent variable, the probability of having a full adopter increases by the value of the Odds Ratio. In this study, the variable OtherY has a larger effect (3.426) on obtaining Full Adoption than AGETR (1.0281). In other words, the probability of a mango grower or contractor choosing to be a full adopter increases 3.426 times with the presence of other sources of income. On the other hand, as the age of mango trees increases by a year, the probability of full adoption increases 1.028 times.

The variables season of flower induction (wet or dry) and level of fruitfly infestation did not exhibit high statistical significance. The impact of these variables was masked by the large number of observations both under full- and partial adopters falling within the condition of high fruitfly infestation and avoiding the risk of loss due to floral and fruit attack by fungal disease. In almost all mango growing provinces in the country, damage to mango fruits due to fruitfly infestation is a problem. Similarly, the losses due to anthracnose may have become a problem throughout the year because of the changing pattern of rainfall in the country. However, these reasons were not generated from the respondents of the study. The validity of these reasons can be verified in future studies.

Social Impact Assessment

When the respondents were asked to compare their level of living before and after the adoption of technology, 82% of full adopters reported that there was an improvement in their living condition while 16% reported otherwise (Table 8). Only 2% said that they were worse off than before. Majority (86%) of partial adopters from all regions considered that their level of living improved after they adopted the need-based spraying (Table 9). Household items bought is a practical way of measuring the income effect of technology adoption. Majority (84%) of the respondents reported that there is an increase in household assets bought after adoption.

Table 8. Level of living of full adopters after adopting the pre-harvest disease management in selected regions, Philippines, 2013

Level of Living	Region I		Region III		Region IV		Region VI		Region XI		Total	
	n = 31		n = 18		n = 12		n = 30		n = 7		n = 98	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Better	26	83	14	75	12	100	26	88	2	28	80	82
Same	5	17	4	25	0	0	2	6	5	72	16	16
Worse	0	0	0	0	0	0	2	6	0	0	2	2

The respondents were asked if the adoption of the need-based spraying would help them attain their aspirations in life. Among full adopters, majority (54%) mentioned that the adoption of the disease management technology will help them in attaining their aspirations while 47% are uncertain if the use of technology will help them achieve their aspirations (Table 10).

Table 9. Level of living of partial adopters after adopting the pre-harvest disease management in selected regions, Philippines, 2013

Level of Living	Region I		Region III		Region IV		Region VI		Region XI		Total	
	n = 6		n = 7		n = 2		n = 5		n = 17		n = 37	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Better	4	70	7	100	2	100	5	100	14	82	32	86
Same	2	30	0	0	0	0	0	0	2	12	4	11
Worse	0	0	0	0	0	0	0	0	1	6	1	3

The same is true for partial adopters. Sixty- five percent mentioned that the adoption of disease management technology will help them achieve their aspirations. Thirty- five percent are uncertain that the use of the technology can help them attain their aspirations (Table 11).

Table 10. Perception of full adopters on whether adopting pre-harvest disease management would help them attain their aspirations in selected regions, Philippines, 2013

Attain their Aspirations	Region I		Region III		Region IV		Region VI		Region XI		Total	
	n = 31		n = 18		n = 12		n = 30		n = 7		n = 98	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	25	81	9	50	4	33	11	37	4	57	53	54
No	0	0	0	0	0	0	0	0	0	0	0	0
Maybe	6	19	10	56	8	67	19	63	3	43	46	47

Table 11. Perception of partial adopters on whether adopting pre-harvest disease management would help them attain their aspirations in selected regions, Philippines, 2013

Attain their Aspirations	Region I		Region III		Region IV		Region VI		Region XI		Total	
	n = 6		n = 7		n = 2		n = 5		n = 17		n = 37	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	6	100	4	57	2	100	1	20	11	65	24	65
No	0	0	0	0	0	0	0	0	0	0	0	0
Maybe	0	0	3	43	0	0	4	80	6	35	13	35

Impact on the Income of Mango Growers

The gross margins in pesos per kilogram of harvest was used to compare the financial benefits generated by the full- and partial adopters of the need-based fungicide spraying and fruit bagging. Gross margin comparison was not done between adopters and non-adopters of the technology. Totally refraining from applying fungicide and bagging is not a common practice in Philippine mango production among mango growers who do not aim to sell their produce on a commercial scale.

Full adopters received an average gross sales of PhP 27.44/kg during the peak harvest season (January to May) of 2013 (Table 12). The cost of fungicide spraying and bagging (variable cost), on the other hand, was estimated to be PhP 11.81/kg. The resulting average gross margin amounted to PhP 15.63/kg. In comparison, partial adopters received an average sales of PhP 21.17/kg while the variable cost was computed to be PhP 5.43/kg. The average gross margin received was PhP 15.74/kg. Significant differences were observed between the gross sales and variable costs of these two types of adopters. Full adopters, on the average, received higher gross sales but incurred a higher variable cost compared with the partial adopters. The larger average gross sales of full adopters, however, did not result in a gross margin that is significantly higher than the partial adopters. Although full adopters achieved higher gross income, the additional cost due to need-based spraying and fruit bagging is also large. In fact, the GM/GS ratio showed that the proportion of the gross margin in relation to the gross sales generated by the partial adopters (74.35) was higher than the one generated by the full adopters (56.96) indicating that the former earned more per unit cost than the latter.

Table 12. Gross margin (pesos/kg) analysis, full adopters vs. partial adopters, peak season, 2013

Item	Type of Adopters			t-Test
	Full	Partial	Difference	2-tailed
Gross sales	27.44	21.17	6.27	*
Variable cost	11.81	5.43	6.38	***
Gross margin	15.63	15.74	-0.11	
GM/GS ratio	56.95	74.35		

*Significant at 10% level

***Significant at 1% level

For the lean harvest season (June to December), no significant differences were found between full and partial adopters in terms of gross sales, variable cost and gross margin (Table 13). In terms of the GM/GS ratio, the partial adopters received a slightly higher value than full adopters, similar to the result obtained for the peak season.

Table 13. Gross margin (pesos/kg) analysis, full adopters vs. partial adopters, lean season, 2013

Item	Type of Adopters			t-Test
	Full	Partial	Difference	2-tailed
Gross sales	38.80	40.07	-1.27	ns
Variable cost	16.67	14.03	2.64	ns
Gross margin	21.36	26.04	-4.68	ns
GM/GS ratio	0.55	0.65		

ns = not significant

Impact on the Supply of Carabao Mango

The beneficial effect of full (spraying and bagging) and partial (no bagging) application of the integrated disease management (IDM) technology on mango production was compared with the effect of the absence of fungicide spraying and bagging. The latter is given as a hypothetical scenario since the survey conducted by the Impact Assessment Team has determined that almost all of the mango growers and contractors are either full or partial adopters of fungicide spraying and bagging. The comparison presented in this study covers Regions I, III and XI where PCAARRD's IDM projects were implemented.

Production data from 2002 to 2012 for the three regions were obtained from the Bureau of Agricultural Statistics (BAS) as input for the analysis. (Data prior to 2002 were not available.) Production for the period 2013 to 2020 was projected using the 10-year historical data. It was assumed that the historical data would represent the volume of harvest that was produced with the aid of the IDM technology following the observation that a significant majority of mango growers and contractors apply the technology, albeit at varying degrees. Following the figures provided by Hextar Venture Phils., Inc., the reduction in annual production for the hypothetical scenario of no fungicide spraying and bagging was estimated using the range of 60% to 80% decrease in the yearly production.. Values for both the lower and the maximum reduction in yield were computed. Figure 1 presents the three sets of production values representing the actual and projected yield, the 60% reduction in yield and the 80% yield reduction.

The analysis showed that at 60% reduction in yield due to the absence of fungicide spraying and bagging, the average annual loss in mango supply was estimated at 201,130 metric tons (MT) valued at PhP 4.54 billion. At 80% yield reduction, the average production loss could reach 268,174 MT with estimated value of PhP 6.06 billion. Turning the analysis around, the estimated values represent the quantity of losses that were prevented (gains) by adopting fungicide spraying and bagging.

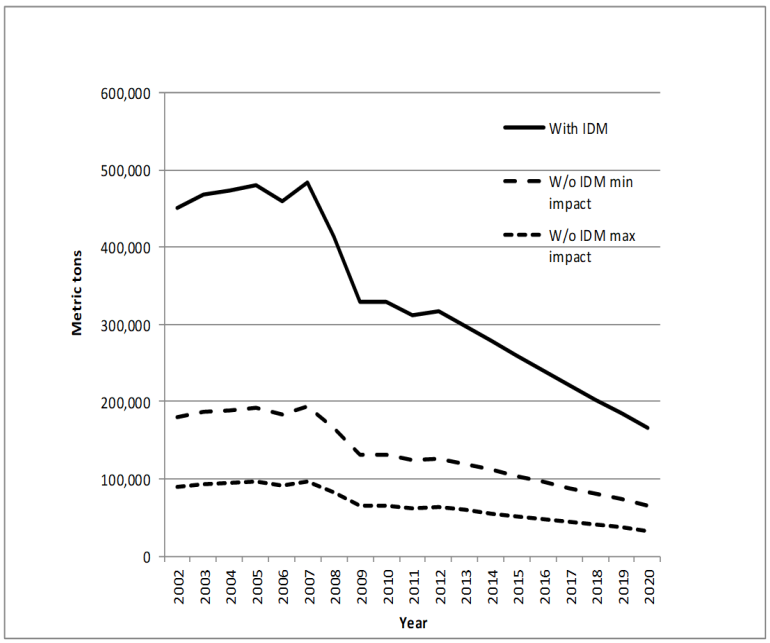

Figure 1. Philippine *Carabao* mango production, Regions I, III and XI, 2002 to 2012 (actual data), 2013 to 2020 (estimates)

Benefit-Cost Analysis

PCAARRD spent PhP 25,307,000.00 to implement Phases I and II of the Science and Technology Anchor Program. Using an average farm gate price of PhP 22.60/kg (PhP 22,600/MT) received by the mango growers during the months of May, August and September, 2012 for Regions I, III and XI, the annual monetary gains considering the minimum and maximum estimates could range from PhP 4.54 billion to PhP 6.06 billion in the three regions.

The average variable cost (cost of farm inputs) amounted to PhP 14,760/MT. The total variable cost per year is the variable cost of the annual additional supply. The fixed production cost per hectare (ha) is the opportunity cost of agricultural land (PhP 5,000.00/ha). The total investment cost that includes the cost of the R & D Anchor Program (PhP 25,307,000) and the cost of establishing the mango farms within the three regions (PhP 30,716.00/ha) was estimated to be PhP 1,307,730,716.00.

The analysis shows that the return on PCAARRD's investment and the mango growers' establishment cost (measured in terms of the Internal Rate of Return) amounted to 148.3% which is higher than the opportunity cost of money. The Benefit -Cost Ratio (at 12% discount rate) was found to be 1.36, indicating that the discounted value of the benefits obtained from the STAP is 36% greater than the combined values of the investment and total production costs.

Conclusion and Recommendations

Spraying and bagging were seen by the adopters as relevant and compatible with the other existing practices on mango production as well as easy to adopt. If a technology is relevant, compatible and easy to adopt, there is a greater chance for potential users to adopt the technology.

Mango growers and contractors are all adopters of the disease management technology. Full adopters are those who used both the need-based fungicide spraying (i.e., fungicide spraying is done only when absolutely necessary to minimize cost) and bagging. Partial adoption can either refer to fungicide spraying without bagging or bagging without spraying. Bagging is considered necessary in areas where fruitfly infestation is high despite the considerable cost involved; it is considered optional in areas where fruitfly infestation is still maintained at lower levels. For market-oriented growers and contractors, total non-adoption of the IDM technology is not an option. Non-adopters are limited to backyard growers or those who do not aim to produce at volumes on a commercial scale.

Although there is no significant difference in the net benefits gained by full adopters from those received by partial adopters due to the higher production cost, the improved quality of mangoes and the reduction in the postharvest disease losses have significant positive effects on the supply of *Carabao* mangoes in the market.

Moreover, all mango growers and contractors assessed their level of living to be better after adopting the technology due to the higher gross income attributed to the increase in yield of good quality mangoes.

Overall, the disease management technology of STAP for mango benefited the mango industry in terms of increased yield, improved quality of mango and reduced post-harvest losses. The benefit-cost analysis shows that the return to R&D investment and mango growers' production costs amounted to more than 100% which is much higher than the opportunity cost of money. The benefits to the industry could still increase if more mango growers adopt the technology. There is a need to further promote the technology to in other mango producing areas in the country.

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