Adoption, yield and profitability of tomato grafting technique in Vietnam

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ABSTRACT

This paper assesses the impact of AVRDC's tomato grafting approach on yield and farm profitability in Lam Dong province and Red River Delta, Vietnam. Tomato grafting is advantageous to farmers suffering from soil-borne disease and abiotic stresses. However, there is scanty information on the extent of knowledge on adoption studies of tomato grafting technology in Vietnam. Based on a farm household survey conducted in August 2012, this paper provides detailed assessment of the adoption and profitability of introducing tomato grafting in the two study areas. Results indicate a 100% (n=225) adoption in Lam Dong province, and a 48% (n=36) adoption in the Red River Delta. The use of rootstock varieties differs in both locations to address location-specific agronomic challenges: tomato variety 'Vimina' (or HW7996) to address bacterial wilt (BW) problem, and eggplant EG203 variety in the Red River Delta to address both BW and waterlogging problem. Estimates from a Cobb-Douglas production function show that tomato grafting increases yield by 30% based. Marketable yield of grafted tomato was significantly larger (71.3 t/ha in Lam Dong Province and 75.0 t/ha in Red River Delta) than nongrafted (48.0 t/ha in Red River Delta). The benefit-cost ratio of grafted tomato production was higher compared to non-grafted due to increased yield and higher premium price. Nonetheless, further validation studies are required, considering the relatively small sample size in the Red River Delta and the high variability of some parameters.

Keywords

AVRDC, vegetable grafting, farm productivity, farm profitability, Cobb-Douglas production function, bacterial wilt, Vietnam,

INTRODUCTION OF TOMATO GRAFTING IN VIETNAM

Tomato (*Solanum lycopersicum*) is one of the important crops in Vietnam. However, during the hot-wet season, its yields are low due to poor fruit setting caused by high temperatures and high incidence and severity of disease , particularly bacterial wilt caused by *Ralstonia solanacearum* (Doan and Nguyen 2005; Nguyen and Ranamukhaarachchi 2010). Bacterial wilt (BW) has been reported in all eight administrative regions of Vietnam in varying degrees of severity. It is usually more severe during the wet season (April-October) than during the drier months (November-March) (Tung 1985; Vinh and Ngo 2006), and can lead to 100% yield loss (Afari-Sefa 2012). Prior to the 1990s, the Red River and Mekong River deltas did not have problems with bacterial wilt in crop production during the drier months (Tung 1985). However, in the mid-1990s, Dung (1997) found that bacterial wilt had become prevalent all year-round especially in Hanoi and the adjacent areas. In Ho Chi Minh City, the rapid expansion of vegetable cultivation including tomato, eggplant and pepper, which are all highly susceptible to the disease, contributed to BW's vigorous proliferation. Farmers also have few options for managing BW once the soil is infested with the bacterium (Wang and Lin 2005). Disease-resistant varieties can be overcome by the pathogen due to its genetic diversity and complex genotype-environment interactions. Likewise, the usefulness of crop rotation becomes limited due to the pathogen's wide range of host plants (Nguyen and Ranamukhaarachchi 2010). Chemical control of soil-borne diseases is also costly and usually unsuccessful (Lin, Hsu, Tzeng and Wang, 2008).

Tomato grafting is an alternative crop management strategy to control BW, root-knot nematode (caused by *Meloidogyne incognita*) and tomato Fusarium wilt (caused by *Fusarium oxysporum* f.sp. *lycopersici*) when high-yielding resistant tomato varieties are unavailable (Wang and Lin, 2005). It combines a flood- and bacterial wilt-resistant rootstock with a high-yielding tomato scion (Aganon, Mateo, Cacho, Bala and Aganon 2002).

AVRDC – The World Vegetable Center started working on tomato grafting in 1992 and introduced the technique to Vietnamese scientists in September 1998 during a one-month training course at AVRDC headquarters in Taiwan. The technique uses the tube splice method, and is elaborately explained in the AVRDC International Cooperator's Guide "Grafting Tomatoes for Production in the Hot-Wet Season" (Black, Wu, Wang, Kalb, Abbass and Chen 2003). It recommends the use of AVRDC BW-resistant varieties *Solanum lycopersicum* 'Hawaii 7996' and *Solanum melongena* 'EG203', coupled with ideal sowing schedule, grafted seedlings and field management activities (e.g., raised beds and shelters, transplanting depth, sucker and adventitious root removal, staking and pruning, pest and water management). From 2002-2006, the technique was disseminated in Lam Dong province (southern Vietnam) in collaboration with the Potato, Vegetable and Flower Research Center (PVFC) under the Institute of Agricultural Sciences for Southern Vietnam (IAS), and to the Red River Delta (northern Vietnam)[1] in collaboration with the Fruit and Vegetable Research Institute (FAVRI) in Hanoi.

Objectives of the study

This paper summarizes some of the findings of a recent study[2] (Genova, Schreinemachers and Afari-Sefa, 2013) conducted by AVRDC which assessed the pattern of adoption, yield and profitability of tomato grafting ten years after its dissemination to Vietnamese farmers in 2002. As this study is based on a cross-sectional data, this paper will not analyze the dynamics of technology adoption nor the impact of tomato grafting on the well-being of farmers nor on the distributional effects. To the best of our knowledge, there are no previous studies on the adoption of

[1] These terms will be used interchangeable in the text: Lam Dong province refers to south or southern Vietnam, and Red River Delta, north or northern Vietnam.
[2] Copy of the full report (Genova et al. 2013) can be downloaded at http://203.64.245.61/fulltext_pdf/EB/2011-2015/eb0205.pdf

tomato grafting in Vietnam or on the dissemination of the proposed tomato grafting technique.

METHODS

The data used for the analysis in this study is based on a field survey conducted by AVRDC in collaboration with local partners, FAVRI and PVFC in August 2012.

The survey covered two major tomato growing regions: Lam Dong province in the south and Red River Delta in the north. These sites were selected by the national collaborators at FAVRI and PVFC. A total of 300 tomato growers were interviewed, 75 respondents (representing 25% of the total sample) from the north and 225 respondents (representing 75%) from the south. The sample size and regional distribution were pre-determined based on the estimated population of tomato farmers, relative importance of grafted tomato in each region, and time and resources available. The agricultural extension officers in Lam Dong province and FAVRI staff, assisted by the commune leaders, provided the main tomato-producing provinces, districts and communes, and the list of tomato farmers in each selected production area. Compiling the list of tomato farmers in both locations proved a daunting task given the time constraints and the challenges faced in identifying tomato farmers; it is therefore likely that the total 1,440 tomato farmers in both regions is an underrepresentation. A two-stage stratified random sampling was used to identify the sample units, i.e. farm households. Areas were stratified by district and by commune in Lam Dong province; and by province, district and commune in the Red River Delta. Tomato growers were allocated across the provinces/districts/communes so that the proportion of farmers sampled for each district/commune is identical to the proportion of farmers in each district/commune in the total population (Table 1).

Information on farmers' production practices, input and output regimes, costs and revenues, and other factors related to tomato cultivation from their most recent production cycle were collected using a semi-structured questionnaire. Detailed data on farm assets, rootstock and scion varieties used, inputs used (quantities, price per unit, family and hired labor), crop outputs and revenue (production distribution, market price per kilogram), changes in crop management practices following the adoption of grafting, pest and disease management, marketing information, training and extension needs, and household income and welfare indicators were gathered, as well as household's socioeconomic information, and their perceptions on the use of grafting in growing tomato.

Profitability analyses

Sources of material inputs, prices per unit, quantities/number of units purchased, and labor were collected for the 2011/2012 production season (farmer's immediate production cycle). In this paper, total operational cost is based on these two cost items. Material inputs consist of seed/seedling cost, animal manure/compost, inorganic fertilizers, fungicides, insecticides, agrochemicals, mulching materials, irrigation/watering costs, staking, harvesting/marketing costs, fuel (transport) and other costs (e.g. rent, etc.). The total cost per input was calculated by multiplying price per unit and quantity/number of units bought and aggregated to arrive at total input costs per respondent.

The following field activities comprise the labor component: land preparation, direct seeding/transplanting, mulching, weed control application, staking, chemical fertilizer application, manuring/composting, pesticide application, watering/irrigation, harvesting, packing/transportation, and other marketing activities. Total person-days of both family and hired labor were aggregated and multiplied with the daily wage rate for nongrafted and grafted tomato cultivation per respondent to arrive at total labor cost. In Lam Dong province, the average daily wage rate was based on the range of values provided by each respondent. Observations with missing values were replaced with the computed average daily wage rate by village, sub district, district or province. The 2011/2012 daily wage rate for an adult farm worker in the Red River Delta was around US$0.41-7.7 per person-day for nongrafted; US$4.3-7.2 per person-day for grafted; and US$2.9-7.2 per person-day for grafted tomato cultivation in Lam Dong province.

Gross income is equivalent to sales. It was calculated by multiplying the marketable crop yield and the produce's selling price. Gross margin was computed as gross income less total variable (i.e., operating costs including material and hired labour) for that reference season. Means, standard deviations and t-tests were computed using STATA version 11 Econometric software package. Extreme values and outliers were excluded in the multivariate regression estimates l using Cook's distance (D) conventional cutoff point of 4/306 (4/n where n is the number of observations).The Cook's D is one of the commonly used measures of test of outliers, wherein it measures the influence of individual cases by looking at the amount of change in the regression coefficients when a particular case is excluded from analysis (Norusis, 2003; Cousineau and Chartier, 2010). The farther it is from zero, which is the lowest value that it can assume, the more influential the point is. In total, 42 out of 321 observations were dropped (15 with missing data in one of the regressors and the rest recognized as influential).

Cobb-Douglas production function

A Cobb-Douglas production function was used to empirically assess the relative influence of grafting technique and other input variables on tomato yield (not marketable yield). The general expression of the Cobb-Douglass functional form is:

$$Y = AL^{\beta}K^{\alpha} \tag{1}$$

where Y is total production (endogenous or dependent variable); L is labor input; K is capital input (L and K are the exogenous or independent variables); A is the total factor productivity; and α and β are the output elasticities of capital and labor, respectively. The model can be linearized as:

$$lnY = \alpha + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \tag{2}$$

where Y_i denotes the yield of the *i*th farmer, X_{ij} the vector of *j*th input used in the *i*th farm in the production process, α_i represents coefficients of inputs which are estimated from the model (α is a constant term), and $e_i$is the error term of the *i*th farm. The α_j is the set of parameters to be estimated that reflect the impact of change on yield given a change in the levels of each input, *ceteris paribus*. This implies an ideal division of yield due to each factor input of production (e.g., seed, fertilizer, labor).

Tomato yield (dependent variable) was assumed to be a function of seed, manure and inorganic fertilizer, fungicide, insecticide, mulching, irrigation, staking, other input costs, labor and three dummy variables (the use of grafting, regional difference, and pest/disease severity) as independent variables. A dummy variable for the use of grafting was included to evaluate the impact of tomato grafting. A location dummy was furthermore included to capture yield variation between the agro-climatic conditions in the two different locations. A pest/disease severity dummy variable was also included because previous studies have shown that insecticide/fungicide productivity is underestimated if pest/disease severity is not specified in the production function (Norwood and Marra 2003). The linearized model has been specified as:

$$lnYIELD = \beta_0 + \beta_1 lnseed + \beta_2 lnma\_fe + \beta_3 lnfung + \beta_4 lninse + \beta_5 lnmulc + \beta_6 lnirri + \beta_7 lnstak + \beta_8 lnag\_oth + \beta_9 lntomdha + \beta_{10} GT\_NGT + \beta_{11} loc\_n + \beta_{12} mode + e_i \quad (3)$$

where:

LNYIELD	Yield level of the *i*th farmer
LNSEED	Natural log of seed/seedling expenditures
LNMA_IFE	Natural log of manure and inorganic fertilizer expenditures
LNFUNG	Natural log of fungicide expenditure
LNINSE	Natural log of insecticide expenditure
LNMULC	Natural log of mulching expenditure
LNIRRI	Natural log of irrigation expenditure
LNSTAK	Natural log of staking expenditure
LNAG_OTH	Natural log of other expenditures
LNTOMDHA	Natural log of labor
GT_NGT	Dummy variable: =1 if grafted, =0 nongrafted
LOC_N	Dummy variable: =1 if Lam Dong province (south), =0 Red River Delta (north)
MODE	Binary pest severity variable: =1 if less severe, =0 otherwise

Three alternative models were estimated for both locations combined (Model 1), and separately for Lam Dong province (Model 2) and the Red River Delta (Model 3).

RESULTS

Adoption pattern and main varieties used

Adopter is defined as a user of the technique whether past or present. Genova, et.al. (2013) found a 100% adoption rate in Lam Dong province and 48% in the Red River Delta. Varieties used for the grafted transplants differ in each location (Table 2). In Lam Dong province, the common rootstock-scion combination was ‘Vimina’ and *S. lycopersicum* ‘Anna F1’ (a hybrid variety of Monsanto). The use of ‘Vimina’ resulted from IAS’ testing for bacterial wilt resistance in 2002/2003 and was subsequently released after evaluation starting in 2004 (Ngo QuangVinh, personal communication, November 7, 2012). In the Red River Delta, challenges to rootstocks posed by waterlogging necessitated the use of *S. melongena* ‘EG203’ paired with *S. lycopersium* ‘Savior’ (a hybrid variety of Syngenta). These popular scion varieties were selected by farmers due to their high yield performance, good appearance, popularity among consumers, and higher number of fruits harvested.

Farmers purchased almost all seedlings for rootstocks and scions from specialized nursery operators in Lam Dong province. In the Red River Delta, about 61-67% of ‘EG203’ and ‘Savior’ came from FAVRI, with the rest sourced from farmer groups and specialized nurseries. It appears that specialized nurseries are not as common in the Red River Delta as in Lam Dong province. One reason could be the economies-of-scale advantage FAVRI has in the sale of rootstock and scion seedlings, which may have prevented the entry of more specialized nurseries in the delta. Also, grafting is a newly accepted farm production technique in the delta with only 48%

farmers using the technique. Setting up these specialized nurseries is knowledge- and capital-intensive and individuals will only invest if proven profitable and huge demand exists.

Yield and profitability of grafted tomato

The average marketable yield of grafted tomato was 71.3 t/ha in Lam Dong Province and 75.0 t/ha in Red River Delta (Table 3). Comparing the performance of grafted tomato in terms of average selling price, gross income and total operational costs in the two locations, all values were significantly higher (p<0.001) in the north. The average selling price in the north was twice than that in the south. Similarly, the total mean operational cost in the Red River Delta was significantly higher, mainly due to high seedling (p=0.008), staking (p=0.000) and labor costs (p=0.000). Seedling cost was also significantly more expensive (p<0.001) in the north at US$ 0.07 per plant versus US$ 0.03 per plant in the south. These results however should be interpreted with caution due to the small number of observations found in the Red River Delta and the high variability of some parameters.

Assessing the profitability performance of grafted versus nongrafted tomato was done only for the Red River Delta due to the 100% adoption in Lam Dong province. Results show significant differences among a number of parameters between grafted and nongrafted tomato in the north. For one, the mean yield and selling price of grafted tomato transplants were significantly higher (p=0.0025) by 56% and 64%, respectively, than nongrafted (Table 4). This resulted in a much larger gross income amounting to US$31,300 per ha for grafted tomato as compared to US$11,537 per ha for nongrafted (p=0.000). However, grafted tomatoes were also more costly to produce, requiring significant amounts of inputs such as seedlings (additional costs of the rootstock, p=0.000), mulching materials (nylon and rice straws, p=0.012) and labor (p=0.010), leading to a higher (p=0.0023) total operational costs. For instance, grafted seedling cost was higher (p=0.000) by US$0.05 per plant than nongrafted transplant.

Nevertheless, because of the significantly higher gross income, farmers using grafted tomato earned US$12,878 per ha more than nonadopters. Based on these results, the benefit-cost ratio was 2.23 for grafted tomato compared with 1.76 for nongrafted tomato, which means that adopters can expect US$2.23 for every US$1 in cost. Further research would be useful to generalize these results for the whole of the Red River Delta, given the small sample size of the nonadopter group. In general, the major cost items in grafting that comprised more than 50% of total operational costs were seedlings, labor, staking and manure and inorganic fertilizers.

Factors affecting tomato yield

Results from the regression analysis show that the coefficients for seedlings, fungicide, insecticide, mulching, labor (person day per hectare [MD/ha]) and grafting are highly significant (p<0.01) for Model 1. A 100% increase in input use would increase yield by 4% for fungicides, 2% for insecticides, 1% for mulching, 9% for labor and 30% for the use of grafting. Increasing seedling expenditures by 100% would result in a yield reduction of 1%. The model shows a decreasing returns to scale of 0.403 (p<0.01) as suggested by the sum of regression coefficients.

Although location was not significant in Model 1, differences between the two locations were observed by comparing Models 2 and 3. In Lam Dong province (Model 2), seed and insecticide costs were found to be highly significant (p<0.01). A 100% increase in seed expenditures corresponded to a 28% increase in yield of grafted tomato. The effect of insecticide use on yield was small at only 1.5% change for a 100% change in insecticide use. In the Red River Delta (Model 3), the impact of grafting on yield was highly significant, as was the expenditure on seedlings, fungicides, insecticide, mulching, and the use of labor. Controlling for all other factors, the use of grafted seedlings led to a 31% increase in yield ($p<0.01$). However, since grafting was relatively new in Red River Delta, a 100% change in seedling expenditures would lead to a 1.3% reduction in yield ($p<0.01$). This could be due to a number of reasons, including low grafted seedling survival rate due to laborers' lack of grafting experience; poor handling of grafted seedlings after purchase and prior to transplanting; and improper field management practices such as graft joints planted below the soil or farmers' failure to remove suckers, which defeat the purpose of grafting. A 100% increase in the use of other inputs in the specified model resulted in a significant ($p<0.05$) increase in yield of 4% for fungicides, 2% for insecticides, 1% for mulching and 6% for labor.

The results from Models 1 and 3 suggest that the use of grafting provides statistically significant yield improvement over the use of nongrafted seedlings. The estimates also suggest that the marginal effect of fungicides, insecticides, and mulching on tomato yields is lower for grafted than for nongrafted tomato. This is consistent with the idea that applying fungicide, insecticide and mulching is redundant when a technology that inherently controls for bacterial wilt, nematodes and other soil-borne diseases is already being used; grafting therefore substitutes for fungicide use as it controls Fusarium wilt.

CONCLUSION

This paper provides a baseline reference of farmers who adopted AVRDC's grafting technique, the case of Vietnam. It shows that in places where bacterial wilt and other soil-borne diseases affecting tomato are a problem, tomato grafting offers very significant monetary benefits to farmers. Mean marketable yield and selling price of grafted tomato transplants are significantly higher ($p=0.0025$) than nongrafted tomato. The Ministry of Agriculture and Rural Development, in partnership with FAVRI, should set up more field demonstration experiments in areas with high bacterial wilt infestation in the Red River delta to encourage more farmers to use the technique vis-à-vis the observable and tangible results from on-site demonstrations. This serves a dual purpose: a) it does not only increase farmers' yield due to the reduction of BW incidence, b) it also accelerates the entry of more specialized nurseries in the area that could potentially drive down the current grafted seedling price of US$ 0.07 per plant closer to the US$ 0.03 per plant in Lam Dong province. Nonetheless, further studies would be useful considering the relatively small sample size in the Red River Delta and the high variation observed for some of the variables. A full cost-benefit evaluation of grafting and non-grafting operations in the Red River Delta as well as an in-depth adoption study of grafting in Lam Dong province could be an ideal follow-up research project to validate the results of this paper now that we have seen the difference in the two locations.

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Table 1. Proportionate stratified sampling by location in Vietnam

Province/District/Commune	Population		Proportionate stratified sample	
	Frequency	*%*	*Frequency*	*%*
Number of tomato growers	**1,440**	**-**	**300**	**-**
Lam Dong province				
a. Communes in Don Duong district				
Da Ron	169	21.9	39	21.9
D'ran	96	12.4	22	12.4
Ka Do	131	17.0	30	17.0
P'ro	101	13.1	23	13.1
Tutra	63	8.2	15	8.2
Lac Xuân	212	27.5	49	27.5
Sub-total	**772**	**100.0**	**178**	**100.0**
b. Communes in DucTrong district				
Lien Nghia	36	17.8	8	17.8
HiepThạnh	14	6.9	3	6.9
GiaChanh	10	4.9	3	4.9
Phu Hoi	69	34.2	16	34.2
Tan Hoi	46	22.8	11	22.8
Tan Thanh	27	13.4	6	13.4
Sub-total	**202**	**100.0**	**47**	**100.0**
Red River Delta				
a. BacNinh province	18	3.9	3	3.9
b. Hai Duong province	97	20.8	16	20.8
c. Nam Dinh province	241	51.7	38	51.7
d. VinhPhuc province	100	21.5	16	21.5
e. Ha Noi province	10	2.1	2	2.1
Sub-total	**466**	**100.0**	**75**	**100.0**

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=300.

Table 2. Main rootstock varieties used in each location

Variety	Description	Reason	Price (US$/seedling)	Source
Solanum lycopersicum 'Vimina' ('Hawaii 7996')	main rootstock variety used in Lam Dong province commonly paired with Monsanto hybrid *S. lycopersicum* 'Anna' F1 (scion)	to protect from soil-borne diseases (caused by fungi, bacteria, nematodes) and other diseases	0.03	private nurseries
Solanum melongena 'EG203'	main rootstock variety used in Red River Delta commonly paired with the Syngenta *S. lycopersicum* 'Savior 1' (scion)	to protect from soil-borne diseases and help control excess moisture (waterlogging)	0.07	FAVRI

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=300.
Note: US$1=VND20,703.4.

Table 3. Sample means of marketable yield, material inputs and labor costs of grafted tomato production in Lam Dong province and Red River Delta, 2011/2012 (US$/ha)

Variable	*Lam Dong province (n=215 obs)*		*Red River Delta (n= 16 obs)*		*Total (n=231 obs)*		*P-value*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	
Seedling cost (US$/plant)	0.03[c]	0.01	0.07[c]	0.01	0.03	0.02	0.0000
Marketable yield (t/ha)	71.27	16.96	74.99	29.37	71.52	18.03	0.6231
Ave. selling price (US$/kg)	0.19[c]	0.15	0.41[c]	0.12	0.20	0.16	0.0000
Gross income	**13,138.2[c]**	**10,902.9**	**31,300.5[c]**	**15,683.3**	**14,396.2**	**12,165.7**	**0.0003**
Material input:	5,881.1	10,761.6	8,499.7	4,314.8	6,062.5	10,460.1	0.0528
Seedling	956.4[b]	198.1	1,863.9[b]	1,184.3	1,019.2	425.8	0.0079
Manure and inorganic fertilizer	1,585.3	767.4	2,060.1	2,380.1	1,618.2	965.4	0.4389
Fungicide	707.8	392.0	748.9	925.2	710.6	446.0	0.8619
Insecticide	247.1	419.5	359.3	618.1	254.8	435.3	0.4853
Mulching	379.1	261.2	389.7	370.9	379.9	269.2	0.9121
Irrigation	157.7	513.2	251.6	1,006.3	164.2	558.3	0.7167
Staking	913.7[c]	553.0	2,325.8[c]	987.3	1,011.5	690.8	0.0000
Other inputs	934.0	10,668.0	500.4	1,746.6	904.0	10,300.5	0.6101
Labor cost:	1,853.2[c]	791.5	7,151.2[c]	3,795.6	2,220.1	1,827.5	0.0001
Labor (person-days/ha)	331.1[c]	138.4	1,314.2[c]	633.1	399.2	326.4	0.0000
Total operating costs	**7,734.3[c]**	**10,791.7**	**15,650.8[c]**	**7,003.9**	**8,282.6**	**10,752.5**	**0.0004**

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=231 observations. Notes: Values are based on 2011/2012 prices; other inputs include agrochemicals; T-test uses Welch's approximation due to small sample size in one group; Level of significance is denoted by a) p<0.05, b) p<0.01, c) p<0.001; US$1=VND20,703.4.

Table 4. Sample means of inputs, outputs and prices of grafted and non-grafted tomato production in Red River Delta, 2011/2012 (US$/ha)

Variable	*Grafted (n= 16 obs)*		*Non-grafted (n= 48 obs)*		*P-value*
	Mean	*SD*	*Mean*	*SD*	
Seed/seedling cost (US$/plant)	0.07[c]	0.01	0.02[c]	0.02	0.0001
Marketable yield (t/ha)	74.99[b]	29.37	47.98[b]	17.68	0.0025
Average price (US$/kg)	0.41[c]	0.11	0.25[c]	0.09	0.0001
Gross income	**31,300.50[c]**	**15,683.34**	**11,536.93[c]**	**5,703.23**	**0.0001**
Material inputs:	8,499.65[b]	4,314.76	4,499.69[b]	6,680.49	0.0084
Seed/seedling cost	1,863.92[c]	1,184.34	216.17[c]	256.47	0.0001
Manure and inorganic fertilizer	2,060.11	2,380.09	1,378.93	3,413.08	0.3832
Fungicide	748.94	925.19	500.03	512.76	0.3192
Insecticide	359.27	618.05	106.47	127.47	0.1244
Mulching	389.71[a]	370.89	119.92[a]	216.76	0.0125
Irrigation	251.57	1,006.28	53.83	262.48	0.4485
Staking	2,325.76	987.3	2,064.29	5,471.63	0.7532
Other inputs	500.37	1,746.61	60.04	96.82	0.3294
Labor cost:	7,151.16[a]	3,795.55	4,265.66[a]	2,502.22	0.0100
Labor (person-days/ha)	1,314.20[a]	633.1	896.04[a]	519.65	0.0255
Total operating costs	**15,650.81[b]**	**7,003.89**	**8,765.35[b]**	**7,484.43**	**0.0023**
Gross margin	**15,649.70[c]**	**11,970.70**	**2,771.59[c]**	**9,604.52**	**0.0007**
Benefit-cost ratio	**2.23**	**1.41**	**1.76**	**1.11**	**0.2376**

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=64 observations.
Notes: Values are based on 2011/2012 prices; other inputs include agrochemicals; T-test uses Welch's approximation due to small sample size in one group; Level of significance is denoted by a) p<0.05, b) p<0.01, c) p<0.001; US$1=VND20,703.4.

Table 5. Econometric estimation results of production inputs on yield
Dependent variable: LNYIELD

Variable	**Pooled (Model 1)**	**Lam Dong province (Model 2)**	**Red River Delta (Model 3)**
	Coef.	Coef.	Coef.
LNSEED	-0.011[b]	0.277[c]	-0.013[b]
LNMA_IFE	0.004	0.066	-0.005
LNFUNG	0.036[c]	0.013	0.037[a]
LNINSE	0.016[b]	0.015[b]	0.018[a]
LNMULC	0.009[b]	0.002	0.012[a]
LNIRRI	0.002	-4.360	-0.009
LNSTAK	0.000	0.001	-0.001
LNAG_OTH	0.004	0.004	0.001
LNTOMDHA	0.086[c]	0.048	0.060[a]
GT_NGT	0.301[c]		0.307[b]
LOC_N	-0.114		
MODE	0.070	0.104	0.025
_CONS	2.612[c]	-2.414[b]	2.972[c]
Number of cases	279	215	64
F-ratio	23.09	12.14	10.61
Prob> F	0.000	0.000	0.000
R-squared	0.433	0.270	0.692

Source: Survey conducted by AVRDC in collaboration with FAVRI and PVFC (2012), n=306 observations.
Note: Level of significance is denoted by a) p<0.05, b) p<0.01, c) p<0.001.