Staff Paper

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Staff Paper 2003-10 **March, 2003**

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ABSTRACT

Since the mid-1980s, bean research in Honduras has focused on the development of improved varieties resistant to key diseases, principally Bean Golden Yellow Mosaic Virus (BGYMV), one of the main constraints to bean production in the country. This paper presents evidence of recent adoption rates of improved bean varieties, the farm-level economic impact of adoption, and the *ex post* rate of return to bean research in Honduras from 1982-2010. Results from a 2001 farm-level survey in the two principal bean-producing regions in Honduras show that 46 to 51% of bean farmers (depending upon the season) have adopted an improved variety, and that adoption is scale-neutral with respect to farm-size and market orientation. Due to the potential problem of sample selection bias in the adoption of disease-resistant varieties, the farm-level impact of the new varieties was estimated using experimental data to approximate the yield differential between resistant and non-resistant varieties under disease pressure, and survey data was used to approximate the frequency of disease incidence in farmers' fields. An expected utility framework assuming risk neutrality demonstrates that adopters gain an average of 20% in bean income from increased yield stability under disease pressure, although these gains are reduced by 7 to 16% due to market price discounts for the resistant varieties. Under base-level assumptions, the economic rate of return bean research in Honduras during the period 1982-2010 is 40 %.

(32 pages including annexes)

JEL Classification Q16: R & D, Agricultural Technology; Agricultural Extension Services

Keywords: Beans; Honduras; Agricultural Research; Technology Adoption; Impact; Rate of Return

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[1] Paper presented at the Conference on Impacts of Agricultural Research and Development, San Jose, Costa Rica, February 4-8, 2002.

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Acknowledgments: Financial and administrative support for this research was provided by the USAID Bean/Cowpea CRSP, the Programa de Investigaciones en Frijol at the Escuela Agricola Panamericana (Zamorano), PROFRIJOL, and DICTA. While gratefully acknowledging these contributions, we take full responsibility for the views expressed in this paper.

1. Introduction

In Honduras, beans are an important crop for small farmers throughout the country, and the most important source of vegetable protein in the diet of a large proportion of rural and urban consumers. Bean research in Honduras has made a major contribution to the bean subsector, primarily through the development of improved bean varieties resistant to key diseases, principally Bean Golden Yellow Mosaic Virus (BGYMV). BGYMV[3] began to spread across Central America in the 1970s, yet was first reported in Honduras in 1985. In 1989, severe BGYMV incidence in Honduras resulted in large bean yield losses (Rodriguez *et al*, 1994), and by 1993, farmers in the two largest growing regions considered the disease their main production constraint (Martel, 1995).

Since 1987, seven improved bean varieties have been released in Honduras, including Catrachita (1987), Oriente (1990), Dorado (1990), Don Silvio (1993), DICTA 113 (1996), DICTA 122 (1996), Tio Canela (1996). Of these varieties, Dorado, Don Silvio, and Tio Canela have BGYMV resistance. These varieties were developed by Zamorano (the Department of Agronomy at the *Escuela Agricola Pan-Americana*) and/or DICTA (the National Bean Program), in collaboration with the Bean/Cowpea CRSP, PROFRIJOL, and CIAT. Because of their scale-neutrality, potential to increase the yield frontier, and on-farm reproducibility, improved varieties are considered one of the best means available to increase the productivity and incomes of small bean farmers and aggregate bean production levels in Honduras (Martel, Bernsten, and Weber, 2000).

In January 2001, the CRSP and PROFRIJOL jointly-funded a survey of bean farmers (N=210) in the Departments of El Paraiso, Francisco Morazan, and Olancho. The survey was designed to generate data required to carry out an *ex post* economic impact assessment of bean research in Honduras, as well to provide Zamorano and DICTA with information about the characteristics of adopters and disadopters of improved bean varieties, and farmers' experience and opinions regarding various agronomic, market, and consumption aspects of the improved and traditional varieties that they planted.

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[3] Bean Golden Yellow Mosaic Virus (BGYMV) is the virus strain that causes Bean Golden Mosaic in Central America and the Carribbean; the strain in Brazil and South America is known as BGMV.

This paper presents results of *ex post* economic impact assessment of bean research in Honduras. The paper begins with a brief description of the bean subsector in Honduras, then discusses the varietal development of improved varieties in Honduras, the survey methodology employed for this study, and finally the impact assessment.

2. Bean Subsector

Honduras is third largest bean producer in Central America, with an annual bean area of 109,000 ha (1994-99 average; SAG, 1999). Within Honduras, among grains, the bean area is second only to maize. Beans are an important source of protein for both rural and urban consumers, and are an important source of income for farmers.

Production. Honduran farmers typically plant two crops during the year. The *primera,* (May/June to July/August) the rainy season, is most important for grain production. In the *primera*, maize is the principal crop; and beans are either intercropped with maize or monocropped. The *postrera* season (September/October to December/January) is a drier season, during which beans are almost exclusively monocropped. The *primera* accounts for approximately 33% of annual national bean production, while the *postrera* accounts for 67% (1995-99 average; SAG, 1999). Beans are grown on both flat land (valleys) and on hillsides. Data are not available to document the percentage of the area in each environment. However, hillside production accounts for an estimated 55% percent of the bean area, versus 45% for the valleys (Juan Carlos Rosas, personal communication). BGYMV is the main bean disease, which is normally found below 1000 m in all growing regions of Honduras and usually in the postrera. Perhaps a more widespread constraint is drought, which is also usually a problem in the postrera.

Together, the Mideast and Northeast regions–the focus of this impact analysis–account for 47% of total national production in the *primera* (1995-99 average) and 67% in the *postrera* (1994-98 average; SAG, 1999). In the Mideast Region, monocropped beans account for 64% of the region's production in the *primera* and 94% of production in the *postrera*. In the Northeast, monocropped beans account for 92% of the region's production in the *primera*, and 95% of production in the *postrera*.

Characteristics of Bean Farmers. In the Mideast, 60% of bean farmers have a total farm area of 3.5 ha or less, whereas in the Northeast, 34% of bean farms are in this category (Martel, 1995). While farmers' bean area is relative small, beans are an important cash crop for most producers.

For example, Martel reported that 50% of Mideast and Northeast bean farmers sold beans, with all of these farmers net-sellers of bean. However, bean sellers vary by the amount sold, with Mideast bean farmers averaging sale of 63% of their total annual bean production, while Northeastern farmers averaged sale of 53% (Martel, 1995). Typically, farmers sell their surplus production to local traders soon after harvest--either at the farm gate or from their home.

Contrary to conventional wisdom, Martel, Bernsten, and Weber (2000) reported that regardless of farm size (<2 ha, 2-10ha, >10 ha), similar proportions (30-50%, depending on cropping pattern) of *primera* bean farmers applied chemical inputs; similar proportions (>30% *primera*; >40%, *postrera*) of flatland and hillside farmers applied chemical inputs; and similar proportion of *primera* farmers who monocropped and intercropped (30-50%, depending on farm size) applied chemical inputs. Likewise, the adoption of improved bean varieties (MVs) appears to be similarly unbiased with regard to farm-size and commercial orientation (Martel, 1995). However, MVs are not adopted in similar proportions as the production environment varies (disease pressure, altitude, etc.). BGYMV-resistant varieties are more frequently adopted by farmers in the valleys, while improved varieties without BGYMV resistance, such as Catrachita, are more readily adopted by farmers in the mountains (*ibid*, 1995). Bean farmers have limited access to support services. Small farmers typically obtain production credit from local money lenders or bean traders, and Honduras has not had a public agricultural extension service since the late-1980s.

Trade. Honduran bean farmers receive a modest level of tariff protection, due to a 25% external tariff within the GATT and a 20% tariff within the Central American Common Market (IICA, 1999). Honduras is largely self-sufficient in beans, barring severe droughts or hurricanes. Imports averaged 2,360 mt from 1994-98, which is equal to only 3.6% of total annual domestic supply (SAG, 1999). Official Honduras export volumes are even lower than imports, averaging 1,700 mt/year from 1994-98 (SAG, 1999). However, Martel (1995) reported that official data underestimates the volume of exports to El Salvador and Nicaragua.

Consumption In recent years (1995-1999), per capita bean consumption in Honduras has averaged 10 kg/person (SAG, 1999). Honduran consumers have a strong preference for light-colored small-red beans. Consequently, the market discounts dark reds by 10-15%. However, in northern areas bordering Guatemala, consumers prefer small-black beans.

3. Bean Varietal Development

3.1 Participating Organizations

In the late 1980s, the Honduran Ministry of Natural Resources significantly decreased funding for agricultural research and extension as a result of structural adjustment. In the wake of these budget cuts, various organizations have attempted top fill the void left by the government in the development and extension of improved bean technologies. With respect to research, the *Programa de Investigaciones en Frijol* in the Department of Agronomy at the *Escuela Agricola Pan-Americana* (Zamorano) became the principal bean breeding program in Honduras, while DICTA, the National Bean Program from DICTA, retained its regulatory mandate**,** as well as some breeding activities.

With respect to the extension of bean technologies, DICTA has promoted artisan seed production programs, although these have been limited in both number and geographic dispersion across the country. Thus, since the late-1980s, improved bean varieties have primarily been extended through DICTA's artisan seed projects, Zamorano-based pilot projects, the sole private commercial seed supplier (Hondugenet, located in the capital, Tegucigalpa), commercial sales by Zamorano, and governmental and non-governmental agricultural development projects–which typically obtained their seed from Zamorano. In the late-1990s, Zamorano and Hondugenet accounted for approximately 75% and 25% of certified been seed sales, respectively. However, the most prominent seed initiative has been the USAID-funded Honduras Post-Mitch Agricultural Recovery program, which multiplied and distributed improved bean seed to farmers across the country, following Hurricane Mitch.

In addition, several other organizations have made major contribution to the development to improved varieties in Honduras, namely PROFRIJOL, the Bean/Cowpea CRSP, and CIAT. Since the early 1980s, PROFRIJOL has provided funding to DICTA and the Bean/Cowpea CRSP has provided funding to Zamorano's bean breeding program. In the mid-1990s, PROFRIJOL began to provide funding to support Zamorano's bean program. In addition, since the early 1980s CIAT has provided germplasm and has collaborated with both DICTA and Zamorano in conducting regional field trials.

3.2 The Varietal Development Process

The development of the six improved varieties considered in this study involved Breeding, On-Farm Testing, National Multi-Locational Trials, Regional Multi-Locational Trials, Varietal

Release, and Seed Multiplication--activities coordinated by Zamorano and/or DICTA, in collaboration with the Bean/Cowpea CRSP, PROFRIJOL and/or CIAT. The specific institutional history of each variety will be discussed in a forthcoming CRSP/PROFRIJOL paper.

3.3 Improved Varieties

Zamorano and DICTA have released seven improved varieties since 1987 (Table 1). Since the late-1980s, Zamorano and DICTA have focused their breeding efforts on identifying sources of resistance to bean golden yellow mosaic virus (BGYMV), a major production constraint in Honduran valleys. Since Dorado, all of the improved varieties released have incorporated Dorado's BGYMV resistance or strengthened it. In addition, Zamorano's current breeding efforts are also focusing on developing varieties with improved heat-tolerance (especially for the lowlands on the Atlantic Coast; Porch, 2001) and drought tolerance.

The following cost-benefit and adoption analysis focuses on six of the improved bean varieties which have been released since 1987. However, a few varieties now considered "traditional" varieties, such as Zamorano (released in 1952) and Desarrural, were released as improved varieties by Zamorano and DICTA decades ago.

Table 1. Improved Bean Varieties Released in Honduras Since 1987

Variety	Color	Reaction to Diseases					Year Released
		BGYMV	BCMV	Rust	WB	CBB	
Tio Canela	small red	R	R	S	I	I	1997
DICTA 122	small red	R	R	S	S	I	1996
DICTA 113	small red	R	R	S	S	I	1996
Don Silvio	dark red	R	R	I	S	I	1993
Dorado	dark red	T	R	I	I	I	1990
Oriente	shiny red	S	R	I	I	S	1990
Catrachita	shiny red	I	R	I	S	S	1987

BGYMV=Bean Golden Yellow Mosaic Virus, BCMV=Bean Common Mosaic Virus, WB=Web Blight, CBB=Common Blight Bacteria. R=Resistance, T=Tolerance, S= Susceptible, I= Intermediate
Source: Martel, 1995; Rosas and Varela, 1996.

3.4 Varietal Dissemination

Seed Distribution Channels Zamorano produces foundation seed of improved varieties, which are multiplied by DICTA (the National Bean Program), Hondugenet (private seed company), and NGOs. Seed is disseminated through various channels. While DICTA has supported an artisan seed program, this program is relatively small in scale. Both Zamorano and Hondugenet sell certified seed directly to farmers, which is packaged in 50 lb bags and sold exclusively from Zamorano's campus and Hondugenet's facilities in Tegucigalpa (the capital). In addition, various NGOs distribute improved seed to participants in their projects and support the development of local farmer seed banks across the country, although they are less active in the Mideast and Northeast than in other regions.

Post-Mitch Distribution The USAID-funded Post-Mitch Agricultural Recovery for Honduras project was the most significant extension of bean technology since the extension service was eliminated. With funding from USAID and the British Department for International Development, Zamorano and 10 independent farmers with irrigation and seed production experience were contracted to multiply a total of 97 mt of improved bean seed (Tio Canela, Dorado, and Don Silvio–approximately equal amounts of each variety) in the *verano* season (December to May), which was then distributed in 10 lbs bags by 41 NGOs to small- and medium-size farmers for planting during the *primera* and *postrera* 1999 seasons (EAP, 2000; Mainville, 2000). A separate component of this USAID project also funded demonstration plots throughout the country, which have helped to introduce farmers to improved varieties. While this project surely exposed many farmers to improved varieties for the first time, only 8% of our sample received seed from an NGO after Mitch. However, this is not surprising since much of the NGO assistance was targeted to other regions of Honduras, which were hit harder (and are generally poorer) than Mideast and Northeast Honduras.

Farmer Seed Source Survey respondents report that they recycle their seed for an average of 2.5 seasons. In *Postrera* 2000, 89% of the farmers either planted saved seed (59%), or obtained seed from a neighbor (29%) (Table A-1). While this evidence seems to support the strategy of artisan bean seed production schemes, the sustainability of such schemes has been questioned (Wiggins and Cromwell, 1995). In addition, data collected which documents farmers' improved varietal use and their knowledge of improved varieties (forthcoming) suggests that as a result of the current state of the seed system--combined with a near void in agricultural extension--many

farmers are not aware of the existence of the most recently released improved varieties, do not know enough about them, or simply do not have access to them.

4. Methodology and Data Collection

4.1 Previous Research

In 1993, the Bean/Cowpea CRSP funded a survey of a random sample of bean farmers (N=239) in the two main bean-growing regions of Honduras (Mideast and Northeast), as well as a survey of traders (N=57) in eight different major Honduran markets (Martel, 1995). The surveys documented adoption rates of improved bean varieties, the socioeconomic characteristic of adopters, the relative farm-level prices of different varieties, and farmers' preferences in varietal selection. This adoption survey and a complementary subsector analysis, which provided increased evidence of the importance of socioeconomic and market factors in farmer adoption of improved varieties, helped Zamorano and DICTA set future breeding priorities.

In 1996, PROFRIJOL and DICTA funded a survey of bean farmers (N=160) in Mideastern Honduras (Viana, Rodriquez, and Escoto, 1997). This study reported adoption rates for Dorado that were quite high[4], possibly due to the heavy concentration of the sample in areas targeted by the National Bean Program (DICTA).

Drawing on the empirical results of these two studies, a study of BGYMV incidence (Morales, 1994), as well as experimental trial data, Johnson and Klass (1999) used a climate-based GIS statistical model to predict (map) BGYMV incidence over time in order to estimate the magnitude of the production losses that were averted as a result of BGYMV-resistant varieties. In addition, they used GIS to document a link between RV adoption and poverty alleviation (as reported by a recent poverty survey).

To estimate the farm-level impact of BGYMV resistant varieties (RV), they argued that estimating the incremental benefit of RV adoption by comparing observed farmer yields of traditional (TV) and resistant varieties would underestimate the returns to the RVs, because of selection bias (Johnson and Klass, 1999; Smale *et al*, 1998; Morris *et al*, 1994). That is, assuming that farmers have a choice of either traditional or improved varieties, and the

[4] For the Mideast region, Martel reported an adoption rate for Dorado of 27% in 1993, whereas Viana *et al* reported an adoption rate of 50% in the same region and year.

probability of virus pressure is not random but rather correlated with farm characteristics, and farmers maximize profit, then it will not be appropriate to interpret the yields of TVs, as observed in sample fields, as representative of what yield would have been if TVs had been planted over the entire bean area (Johnson and Klass, 1999). Observed yields of TVs will be higher than what would have been observed in the absence of the option of an RV. Thus, the appropriate comparison is between the yields of TVs and RVs in experimental trials, which control for the biases described above (Smale *et al*, 1998; Morris *et al*, 1994).

This study provides updated estimates of adoption rates and incremental farm-level benefits of adoption of improved varieties for use in cost-benefit analysis of bean research in Honduras[5]. To this end, a survey of bean farmers in Mideast and Northeastern Honduras (N=210) was implemented in January-February 2001 and secondary data were collected.

4.2 Sampling Procedure

The 2001 farmer survey targeted the Mideast (El Paraiso and Francisco Morazan department) and Northeast (Olancho department) regions, which together account for about one-half of annual bean production in Honduras. In each of the three departments, 70 farmers were selected using the following methodology. Using bean area and production data from the 1993 Agricultural Census, a list of villages was constructed for each department which represented a cumulative of 80 percent of bean area in that department. This list was then divided into deciles by cumulative bean area, and one village from each decile was selected at random. Care was taken to ensure that the cumulative number of villages selected from a given municipality did not exceed its share of the Department's total bean area[6]. Selected villages beyond a municipality's share were replaced by the next random selection within the decile. Thus, this sample selection method was constructed to focus upon "area" adoption rates for benefit-cost analysis, yet to ensure that village selection remained representative of the department's bean area in terms of village geography and size.

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[5] Analysis of the characteristics of adopters and disadopters forthcoming.

[6] For example, within the list of villages that comprised a cumulative 80% of El Paraiso bean area in the 1993 census, the Danli municipality accounted for approximately 40% of total department bean area. Thus, during the village selection process, no more than 4 villages in the Danli municipality were allowed to be selected at random.

4.3 Characteristics of the Survey Respondents

Bean farmers in the Mideast and Northeast regions of Honduras are typically old, male, have little education, cultivate small farms, plant 1-2 ha to beans, get modest yields (400-650 kg/ha), and apply both fertilizer and insecticide.

Age, Gender, Education. The respondents' average age was 49 (range =17 to 86 years). In terms of age cohorts, 12% were <30, 22% were 31-40, 20% were 41-50, 21% were 51-60, 19% were 60-70, and 6% were >70 years of age. Only one of 210 respondents was female. The respondents had completed an average of three years of schooling (range=0-13 years). Approximately 29% had no education, 65% had 1-6 years, and 6% hand >6 years of schooling.

Farm Size, Bean Area, Yields, and Elevation. The respondent's total farm area averaged 11.1 hectares (ha) (range=0.5 ha to 600 ha–including pasture), yet the median total farm size was 3.5 ha as only a few farmers had large areas in pasture. In the Mideast region, 54% of the respondents had a total farm area < 3.5 ha, and 86% had a total farm area < 10 ha. By contrast, in the more extensive Northeast region, 46% of the respondents had a total farm area < 3.5 ha, and 78% had a total farm area < 10 ha. In *primera* 2000, the respondents' bean area (N=170) averaged 1.52 ha, with an average yield of 652 kg/ha (CV=68%). In the *postrera*, their bean area (N=202) averaged 2.13 ha, with an average yield of 424 kg/ha (CV=84%). The mean farm was 923 m above sea level (range=475 to 1,700 m).

Input Use. In *primera* 2000, most respondents (59%) applied compound fertilizer (12-24-12), 49% used urea (45-0-0), 30% applied both; and 26% used neither. In *postrera* 2000, 48% of the respondents applied compound fertilizer (12-24-12), 45% used urea (45-0-0), 25% applied both; and 32% used neither. In *primera* 2000, 73% of the respondents applied insecticide and 26% used fungicide. In *postrera* 2000, 65% of the respondents applied insecticide and 19% used fungicide.

Bean Sales In *primera* 2000, 75% of the respondents sold at least part of their bean harvest. Of those who sold beans in the *primera*, they sold an average of 65% of their harvest. Most *primera* farmers sold their beans either immediately at harvest (60%) or within a month after harvest (25%). For *postrera* 2000, 63% of the respondents sold at least part of their bean harvest. Of those who sold beans in the *postrera*, they sold an average of 80% of their harvest. As in the *primera*, most *postrera* farmers sold their beans either immediately at harvest (70%) or within a month after harvest (25%). Ninety percent of the sales transactions occurred at the farmer's field

or house. Thus, few farmers have the storage or credit capacity to wait for higher post-harvest prices, nor the transport to find a higher price than that offered by a local intermediary.

4.4 Impact Analysis

An economic surplus model is applied to quantify the aggregate benefits of improved varietal adoption in Honduras (Alston, Norton, and Pardey, 1995). The methodology involves estimating the percentage downward shift in the commodity supply curve, resulting from the introduction of the new varieties, and calculating the change in total economic surplus as a result of this supply shift. The shift factor in a given year is derived from the variety's reduction in per-unit cost and the varietal adoption rate. The projected per-unit cost reduction is derived from the changes in yield and cost of production per hectare at the farm-level. The farm-level changes in yield between "with" and "without" scenarios are explained in greater detail in Section Six. A research cost stream is constructed, and Net Present Value and Internal Rate of Return are used as performance indicators.

5. Adoption of Improved Bean Varieties

Primera In *Primera* 2000, 51.2 % of the respondents planted an improved variety, principally Dorado (30 %) or Tio Canela (10.6 %), and 62.4 % planted a traditional variety (Table 3). Approximately 13 % of the farmers grew both an improved and a traditional variety. Typically, farmers who plants both an improved and a traditional variety plant a small proportion of their fields to TVs, which is intended for home consumption---due to preferred characteristics--and a larger area to MVs, intended for the market. While the farm-level market price of the MV is typically lower than that of the TV, farmers plant MVs to reduce the risk of yield loss due to diseases (especially BGYMV) to which TVs are susceptible. If the percentage yield loss avoided is larger than the MV price discount, the farmer's average revenue from market sales is higher with an MV.

Table 3. Farmer Varietal Use in *Primera* 2000, Honduras				
Variety	**Total [a] (%)**	**El Paraiso (%)**	**F. Morazan (%)**	**Olancho (%)**
Tio Canela	10.6	10.2	13.3	7.8
Dorado	30.0	28.8	28.3	33.3
Don Silvio	4.1	1.7	6.7	3.9
Catrachita	6.5	0.0	18.3	0.0
DICTA 122	0.0	0.0	0.0	0.0
DICTA 113	0.0	0.0	0.0	0.0
Total MV	51.2 [b]	40.7	66.6	45.0
Total TV	62.4 [b]	67.8	50.0	70.6
	N=170	N=59	N=60	N=51

Source: CRSP/PROFRIJOL Farmer Survey, 2001 (N=210)

[a] Unweighted percentage using the entire sample (N=170; *i.e*. farmers who planted in *primera*)
[b] As some farmers planted more than one variety, the total is greater than 100%.

Postrera In *Postrera* 2000, 46.2 % of the respondents planted an improved variety, principally Dorado (25.7 %) or Tio Canela (11.4 %), while 76.2 % of farmers planted a traditional variety (Table 4). Approximately 22 % of the farmers planted both an improved and a traditional variety.

Table 4. Farmer Varietal Use in *Postrera* 2000, Honduras				
Variety	**Total [a] (%)**	**El Paraiso (%)**	**F. Morazan (%)**	**Olancho (%)**
Tio Canela	11.4	9.0	13.8	11.4
Dorado	25.7	26.9	21.5	28.6
Don Silvio	4.0	1.5	6.2	4.3
Catrachita	5.0	0.0	15.4	0.0
DICTA 122	0.0	0.0	0.0	0.0
DICTA 113	0.5	1.5	0.0	0.0
Total MV	46.1 [b]	37.4	56.9	44.3
Total TV	76.2 [b]	76.1	60.0	91.4
	N=202	N=67	N=65	N=70

Source: CRSP/PROFRIJOL Farmer Survey, 2001 (N=210)

[a] Unweighted percentage of the entire sample (N=202; *i.e*. farmers who planted in *postrera*)
[b] As some farmers planted more than one variety, the total is greater than 100%.

Adoption by Region There is no significant difference in MV use across administrative regions (Mideast versus Northeast). This is an interesting development**,** given that there was a significant difference in regional adoption rates in 1993, when significantly more Mideast farmers grew MVs (Catrachita, 27%; Dorado, 27%) than Northeast farmers (Catrachita, 16%; Dorado, 7%[7]) (Martel, 1995). The regional difference in MV adoption in 1993 was likely due to both the greater physical presence of Zamorano and DICTA in the Mideast, as well as the focus of the DICTA artisan seed programs in the Mideast region (El Paraiso and Francisco Morazan) (Martel, 1995).

While it is clear that a regional difference in adoption no longer exists, it is unclear how this occurred. One explanation may be that–given the weakness of the formal seed dissemination system–improved bean seed diffuses slowly through informal channels. This process begins in the Mideast–due to the reasons cited by Martel–yet eventually improved seed moves into the Northeast (Olancho). This hypothesis is supported by the fact that Dorado and Don Silvio

[7] Significance level of α=0.05.

reached their ceiling adoption level a few years ago, while Olancho is just now approaching a similar adoption level. However, this explanation is contradicted by the rather quick adoption of Tio Canela in Olancho by 2000 (to levels equal those of the Mideast).

An alternative explanation could be that USAID's Post-Mitch seed program (1999) introduced Dorado, Don Silvio and Tio Canela to many new Olancho farmers While there is not a significant difference in the number of our survey respondents in the two regions who received seed directly from an NGO after Mitch, it is possible that by 2000, the initial NGO seed delivered (1999) to Olancho was diffused among neighbors, which may include some of our respondents. This hypothesis is supported by the fact that there was a statistical difference (α=0.04) in MV adoption between the regions in *primera* 1999 (***i.e.,*** prior to the Post-Mitch seed delivery, which started in *primera* 2000--although most of the seed was distributed for *postrera* 2000), and a difference at the level (α=0.16) in *postrera* 1999. However, by *postrera* 2000, there was clearly no statistical difference (α=0.88) between regional adoption of MVs.

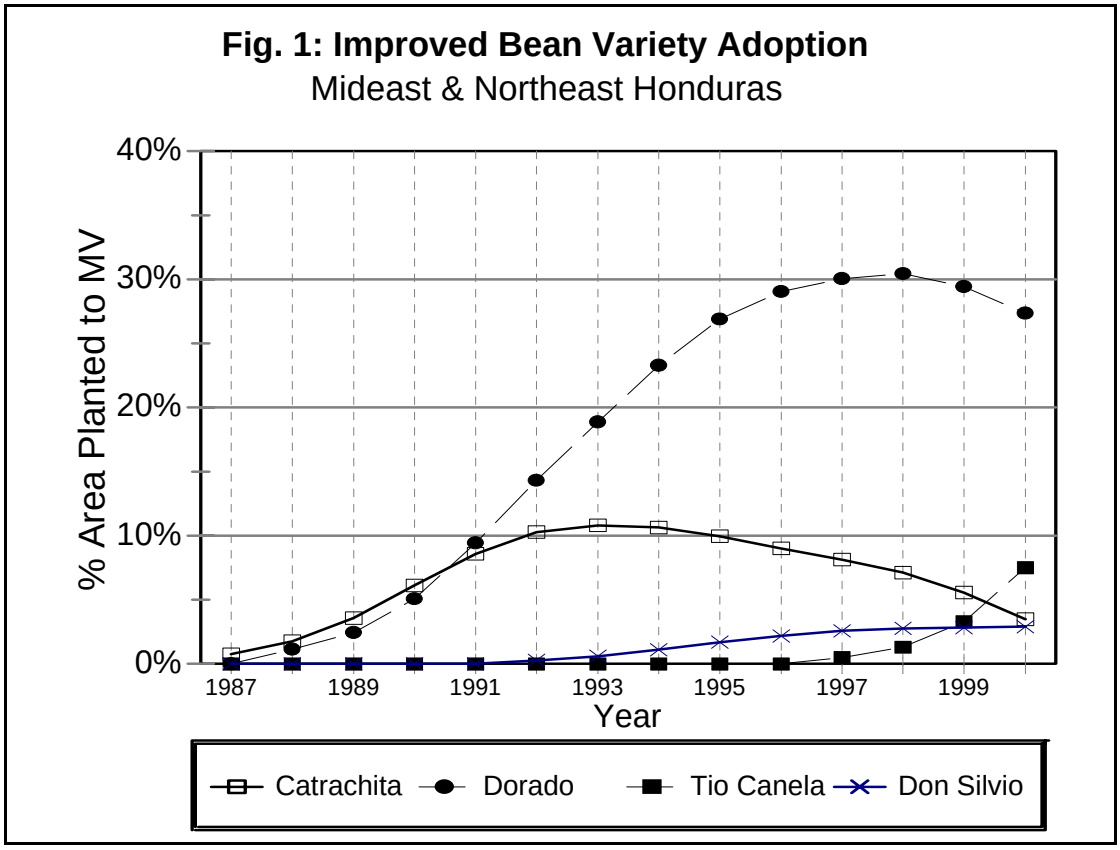
Adoption and BGYMV pressure Because one of the principal advantages of Dorado, Don Silvio, and Tio Canela is BGYMV resistance, we would expect to find a higher percentage of resistant variety (RV) adopters in areas with high BGYMV pressure. Using altitude, as well as historical knowledge of BGYMV areas of incidence as a proxy for BGYMV pressure[8], there is a statistical difference (α=0.04) between the adoption of resistant varieties (Dorado, Don Silvio, and Tio Canela) in "BGYMV" areas (typically with altitude <1,000 m) and "non-BGYMV" areas in both *primera* and *postrera* 2000. However, as farmers in the "non-BGYMV" areas (mountains) often live in quite remote communities, it is unlikely that they have the same level of access to information about resistant varieties and the seed itself, as do farmers in the valleys.

Adoption by Farm-size and Market Orientation Defining small farmers as those having < 3.5 ha of total farm area, the adoption of MVs in 2000 is scale-neutral by farm size, which concurs with Martel's finding in 1993 (Martel, 1995). Defining market orientation simply by whether or not each respondent sold beans in a given season, the adoption of MVs is also scale-neutral by market orientation (for both primera and postrera 2000).

Adoption Over Time Area adoption curves were constructed using a logistic function fit to data points from the 1993 and 2000 farmer surveys in the Mideast and Northeast regions (Martel,

[8] Compiled by Dr. Juan Carlos Rosas, Programa de Investigaciones en Frijol, Escuela Agricola Panamericana, Zamorano, Honduras.

1995; CRSP/PROFRIJOL Bean Farmer Survey, 2000)--weighting the annual MV bean area by the seasonal and regional shares of the annual total of the two regions (Figure 1). Dorado is clearly the most widely-adopted MV, although its area has declined slightly in the last few years. Some of the Dorado disadopters have switched to Tio Canela, the area of which has increased rapidly since its release in 1997. Don Silvio has never been widely adopted, and perhaps would have accounted for a negligible area by 2000, if it hadn't been included in the USAID Post-Mitch distribution program. While Catrachita adoption grew in the early-1990s, its use has declined steadily since then.



Disadoption of MVs As for those who planted the improved varieties at least once, yet discontinued use of the variety, the principal reason given for disadoption in the case of each variety – for 32 to 50 % of the disadopters – was "low market price." The second most prevalent

reason for disadoption (from 10 to 15 %) was "lost seed / no seed available," which demonstrates the constraint to varietal use posed by an informal seed system.

Preliminary analysis indicates that 32 % of the respondents have disadopted Dorado, while 11 % have disadopted Tio Canela. While some of the disadopters of Dorado switched to Tio Canela, the principal reason given by farmers for disadopting Dorado is to move to a TV with a better relative market price. This suggests that for these farmers, BGYMV pressure has diminished in recent years in their area, or that the yield gain of Dorado–under BGYMV pressure– does not compensate for the price discount.

6. Impacts of Improved Bean Varieties

6.1 Introduction

Farm-level profitability is the sole indicator of impact in the following analysis. Given that disease-resistant varieties historically have received price discounts in the market (Martel, 1995), gains in profitability due to the more stable yields of BGMV resistant varieties (RVs) are tempered by losses in profitability, due to the RV's poorer market characteristics. The following sections present evidence from experimental and survey data on varietal yields and prices, from which assumptions are made of the farm-level yield gains and price discounts of MV adoption.

6.2 Yield

Experimental Yields. In yield performance trials conducted on farmers' fields (N=53) across Honduras[9], Tio Canela averaged 1,200 kg/ha, compared to an average of 850 kg/ha for the local check–which represents a yield improvement of 41% above the local check variety (Rosas and Varela, 1996). In experimental trials under BGYMV pressure, Tio Canela yielded 50% more than the local check; and Dorado yielded 20% more than the local check in farmers' trials, and 50% more under BGYMV pressure in experimental trials. Finally, Catrachita yielded 20% more than the local check in farmers' field trials.

Survey Yields. The survey respondents' yields are quite variable, across varieties, seasons, and years (Tables 5-8). During both the *primera* and *postrera* (1998-2000), department yields (average of all varieties) were highest in Olancho (Tables 5 and 6), which concurs with official

[9] Farmer trials included a local check, typically a TV, and the farmers' choice of fertilizer application rate and management practice (the same for both Tio Canela and the TV).

aggregate statistics. The *postrera* 1998 yields reflect the devastation of Hurricane Mitch (October 1998)[10].

Table 5. Bean Yields by Department, *Primera* 1998-2000, Honduras

Department	*Primera* 2000			*Primera* 1999			*Primera* 1998		
	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N
El Paraiso	521	65	58	678	78	53	593	93	50
F.Morazan	653	73	60	641	67	60	624	81	54
Olancho	800	60	51	832	52	49	692	79	46
Total	652	68	169	711	66	162	635	84	150

Source: CRSP/PROFRIJOL Bean Farmer Survey, 2001
CV=coefficient of variation (standard deviation divided by the mean)

Table 6. Bean Yields by Department, *Postrera* 1998-2000, Honduras

Department	*Postrera* 2000			*Postrera* 1999			*Postrera* 1998		
	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N
El Paraiso	496	82	67	554	80	65	214	93	65
F.Morazan	339	95	65	608	77	68	214	140	59
Olancho	481	76	68	662	57	67	280	96	66
Total	424	84	200	589	71	200	233	125	190

Source: CRSP/PROFRIJOL Bean Farmer Survey, 2001
CV=coefficient of variation (standard deviation divided by the mean)

Varieties. During the *primera* (1998-2000), varietal yields varied considerably from year-to-year. In 2000, 1999, and 1999, respectively, the highest yielding varieties were Tio Canela (869 kg/ha), Dorado (926 kg/ha), and Dorado (785 kg/ha). In all years, the TVs produced a higher

[10] While hurricanes are a constant threat to agricultural production in Central America, Hurricane Mitch (*postrera*, 1998) had an especially devastating impact on bean production in Honduras. According to the Ministry of Natural Resources (SAG, 1999), an estimated 93% of the bean area in the Mideast (19,500 ha of the region's 21,000 ha) and 14% of the bean area in the Northeast (2,700 ha of the region's 20,000 ha) suffered crop losses.

yield than Don Silvio and Catrachita; and a higher yield that Tio Canela in 1998–although the sample size for these varieties was relatively small in each year. However, because the coefficient of variation (CV) for all varieties in all years were high (ranging from 63-112%), MV yields were only significantly higher than TV yields for the case of Dorado in 1999 (α=0.06).

Table 7. Bean Yields by Variety, *Primera* 1998-2000, Honduras

Variety	*Primera* 2000			*Primera* 1999			*Primera* 1998		
	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N
Tio Canela	869	73	18	753	75	12	575	113	5
Dorado	724	66	50	923	63	50	785	72	49
Don Silvio	556	80	7	561	70	7	285	51	2
Catrachita	458	77	11	436	77	11	588	94	18
All TVs	632	65	104	701	62	102	595	84	89

Source: CRSP/PROFRIJOL Bean Farmer Survey, 2001
CV=coefficient of variation (standard deviation divided by the mean)

During the *postrera* (1998-2000), varietal yields were also quite variable from year-to-year (Hurricane Mitch hit Honduras during *postrera* 1998). From 1999 to 2000, the highest yielding varieties were Tio Canela (791 kg/ha), Don Silvio (796 kg/ha), and Dorado (624), respectively. The TVs produced a higher yield than Catrachita and Dorado in 2000, and than Catrachita and Dorado in 1999–although the N for some of these varieties was relatively small in each year[11]. However, because the CVs for all varieties in all years were high (ranging from 46-90%), MV yields were only significantly higher than TV yields in the case of Tio Canela and Don Silvio in 1999 (α=0.16).

[11] It should be noted that the wide range of yields and the diversity of environmental conditions by location makes it difficult to compare yields of a given MV with the TV yield of the entire sample. For example, 10 of the 12 Catrachita growers in our sample (in 2000) are from 2 villages in Francisco Morazan. In these 2 villages, Catrachita yields are higher than those of TVs. Yet, because these villages' yields are quite low compared with the entire sample, Catrachita appears to be a low-yielding variety.

Table 8. Bean Yields by Variety, *Postrera* 1998-2000, Honduras									
Variety	*Postrera* 2000			*Postrera* 1999			*Postrera* 1998		
	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N	Yield (kg/ha)	CV (%)	N
Tio Canela	537	93	23	791	53	14	190	200	7
Dorado	369	92	52	624	90	58	268	139	55
Don Silvio	552	74	8	796	46	8	389	141	2
Catrachita	211	68	10	483	80	12	165	176	19
All TVs	446	80	151	612	63	133	239	118	124
Source: CRSP/PROFRIJOL Bean Farmer Survey, 2001 CV=coefficient of variation (standard deviation divided by the mean)									

Incremental Yield and Stability of MVs Given that several of the MVs have BGYMV disease resistance (Don Silvio, Dorado, and Tio Canela), one would expect that their yield CV would be lower than the CV of TVs. However, as shown in Tables 7 and 8, the CV among TVs and MVs are relatively similar in both the *primera* and *postrera*. In addition, statistical comparisons of respondents' yield by variety offer little evidence that MVs have significantly higher observable yields than TVs. Multi-variate regression analysis was used to test for yield differentials between resistant MVs and TVs, controlling for numerous factors besides variety which influence yield (fertilizer use, altitude, region, farmer socioeconomic characteristics, *etc*). Initial yield regressions did not support the hypothesis that MVs are higher-yielding than TVs, except in the case of Tio Canela in *primera* 2000. While this is not surprising--given the difficulty in estimating production functions with farmer survey data--additional econometric specifications will be explored.

While the observed performance of any technology under farmer conditions is expected to fall considerably short of the experimental trial results, the fact that MV yields and CVs are quite similar to those of TVs--combined with high adoption rates--suggests that selection bias is present. That is, assuming that most farmers in high-risk BGYMV areas are no longer growing TVs (which is a reasonable assumption, given the high adoption rates), then currently observed TV yields are likely much higher than they would have been, without the availability of resistant varieties (Johnson and Klass, 1999). Respondents' comparisons of the varieties that they have

planted in recent years provides evidence to support this hypothesis.

For example, 16% of current Dorado growers grew a TV immediately before Dorado. These farmers (N=33) cite good yield (9%) as the principal advantage of Dorado, followed by "good resistance to diseases, drought, and insects" (27% together). For these growers, the principal disadvantage of Dorado is "low price" (67%), while the principal advantage of their TV (previous variety) is "good price" (45%), followed by "short crop cycle" (18%). Additional reported advantages of TVs are their superior culinary characteristics. Therefore, it appears that by choosing to plant Dorado, these growers are choosing "yield" and "resistance" qualities over "price"and "culinary" considerations.

In addition, these growers were also asked to directly compare their current variety with their former one, in terms of disease resistance, drought resistance, and culinary characteristics. Specifically, they were asked which of the varieties was better in each category, or if they were equal (Table 9). For both the farmers who had grown a TV prior to a RV (N=51) and the farmers who grew a RV and switched back to a TV (N=51), it is clear that both categories of farmers agree that RVs have better disease and drought resistance, while TVs have better culinary characteristics. This implies that the farmers who switched away from the TV value the culinary characteristics more highly than the other characteristics because they are primarily subsistence farmers, they don't experience a high incidence of disease and/or drought, or the yield loss to disease/drought is less than the value loss due to a lower market price.

Table 9. Farmer Comparisons of Varietal Characteristics, 2001

Comparison Category		Farmers who switched from an TV to a RV[a] (%)	Farmers who switched from an RV to a TV[b] (%)
Disease Resistance	RV better: TV better: equal:	84 4 12	67 20 14
Drought Resistance	RV better: TV better: equal:	84 4 12	53 29 18
Culinary Characteristics	RV better: TV better: equal:	12 67 22	13 74 13

RV=resistant MV, [a]: N=51, [b]: N=51 Source: CRSP/PROFRIJOL Farmer Survey, 2001

An alternative explanation for the lack of observable yield differentials is simply that the RVs do not outperform TVs under farmers' conditions. However, farmers' varietal choices, namely the continued high rates of adoption for Dorado, combined with their opinions regarding varietal advantages, strongly suggest that farmers who continue to plant Don Silvio, Dorado and Tio Canela experience gains in yield stability (yield loss avoided) from the RV, which are higher on average than the market price discount. A complementary explanation is that farmers' risk aversion implies that they prefer the lower but more stable revenues attributed to the RVs than the higher but more variable revenues of the TVs. However, while we can easily measure the market discount, the yield gain over a hypothetical TV in a "without resistant MV scenario" is much harder to estimate. The treatment of risk is not considered here. Thus, in the following benefit-cost analysis, we rely upon experimental yield trials under disease pressure to estimate parameters for the yield gains from resistant MVs.

6.3 Prices

Consumer Preferences As is the case throughout Latin America, Honduran consumers have strong preferences for various characteristics of dry beans--color, size, shape, freshness, cooking time, consistency when cooked, and the texture of the sauce all influence the farm-level price of dry beans. Martel has extensively documented Honduran consumer preferences and attitudes towards different bean varieties, and corresponding price differentials between varieties, using both farm-level and trader-level surveys (Martel, 1995). He found that on average, farmers received 16% less for Dorado (due to its dark red color), compared to traditional varieties, and 11% less for Catrachita (due to its undesired consistency when cooked)[12]. Zamorano/DICTA's subsequent release of Don Silvio (1993) did not improve upon the price discount, as Don Silvio is very similar to Dorado in color. However, by 1997, Zamorano released Tio Canela, which is a lighter red color than Dorado, and which also out-performed Dorado in yield trials under experimental and farmers' management, and in resistance trials under experimental management (Rosas and Varela, 1996).

In light of the introduction of Tio Canela in 1997, an important research question is whether or not Tio Canela commands a higher farm-level price than Dorado, and whether or not the price differentials for the other varieties have changed since 1993. If a price differential between Tio

[12] Martel interviewed 210 farmers in the Mideast and Northeast regions, and he interviewed 57 traders in the eight largest urban areas of Honduras (Martel, 1994).

Canela and Dorado still exists, then it is expected that farmers who switch from Dorado to Tio Canela would earn higher average revenues, relative to Dorado. What is less clear is whether or not a lower price differential between Tio Canela and TVs would entice more TV growers--perhaps those in low-risk BGYMV areas--to adopt Tio Canela.

Farm-level Prices For *primera* 2000, the respondents' mean farm-level price was $US 0.46/kg (N=147) (Table 10), while for the *postrera* the mean price was $US 0.51/kg (N=147). Given the dispersion of sale prices over time and space, regression analysis was used to control for time of sale, region, and remote areas by season. The results of various specifications show that the Dorado and Don Silvio price discount for the *primera* 2000 is in the range of -15% to -20%, while for *postrera* 2000 the discount is in the -10% to -15% range. Tio Canela and Catrachita price differentials are not significant in any of the model specifications[13], although this may be due to their small sample size.

Table 10. Farmer's Bean Prices, Honduras, 2000

Variety	Primera 2000				Postrera 2000			
	Farmer Price ($US/kg)	N	CV (%)	% price discount for MV[a]	Farmer Price ($US/kg)	N	CV (%)	% price discount for MV
Tio Canela	$0.47	11	31	- 4.1	$0.47	10	20	- 9.6
Dorado	$0.38	41	26	- 22.4	$0.46	27	27	- 11.5
Don Silvio	$0.32	4	14	- 34.7	$0.47	5	20	- 9.6
Catrachita	$0.52	9	32	6.1	$0.57	5	17	9.6
All Traditional Varieties	$0.49	80	27	na	$0.53	98	23	na
All Varieties	$0.46	147	30	na	$0.51	147	25	na

Source: CRSP/PROFRIJOL Farmer Survey, 2001
[a] Compared with TVs
CV=coefficient of variation, na=not applicable

[13] The apparent Catrachita price premium in Table 10 is a local phenomenon; in the two sample villages in which Catrachita is grown, Catrachita commands the same price as TVs, controlling for time of sale.

Wholesale Prices In addition to the farmer survey, a small rapid-appraisal survey of wholesalers was completed in Danli, El Paraiso (N=5) and Tegucigalpa, Francisco Morazan (N=11) at the time of the survey[14] (about a month after the *postrera* harvest). The objective of this survey was to get a rough estimate of wholesale-level price differentials between specific MVs and TVs. Seven clear 1-kg bags, each containing a MV from Zamorano/DICTA, were shown to each participating bean wholesaler, who was asked at what price he/she would buy each specific variety (the bags did not contain the variety name). In addition, each trader was asked the prices at which he/she was currently buying his/her highest-volume TVs.

The results for Dorado and Don Silvio concur with the prices that farmers report in the farm-level survey, as well as with prior surveys at the farm and wholesale levels (Martel, 1995). Dorado and Don Silvio receive a 16% price discount, compared to TVs. Surprisingly, Tio Canela receives almost as large a price discount as Dorado, which differs from our finding at the farm-level. Catrachita receives a 5% price discount. While currently released resistant varieties continue to face a price discount, Zamorano's forthcoming variety, Milenio (which has the BGYMV resistance of Tio Canela), commands a smaller price discount (7%) than Tio Canela with respect to TVs.

6.4 Farm-level Incremental Net Benefits of Adoption

Incremental Yields For the following benefit-cost analysis, we assume for simplicity that farmers are risk-neutral, and we assume BGYMV frequency and yield loss averted by RV use as described in Table 11. There is no farm-level empirical data on either yield loss or BGYMV frequency,[15] thus we assume that yield loss to BGYMV ranges from 0 to 50 %, and that there is yield loss in four out of five years. Our frequency assumption is based upon respondent information.[16] Our respondents were asked to identify from pictures which (if any) bean diseases

[14] The wholesaler surveys in Danli were completed in late January, 2001, while those in Tegucigalpa were completed in early January, 2002. As our main interest is in the relative (not absolute) price difference between the MVs and the TVs, this data remains useful even though collected a year apart.

[15] Johnson and Klass incorporated Morales' work (1994) on BGYMV incidence in one crop year into a GIS climate-based model to predict BGYMV incidence over time across Honduras.

[16] We showed respondents pictures of the six principal bean diseases in Honduras (without corresponding names), and asked them to identify the two diseases which have caused the most damage to their bean crop in the past 5 years. Thirty-percent of the respondents listed the BGYMV picture as one of their two principal diseases. The respondents were then asked in which season (primera, postrera, or

most damaged their yields in the last five years. Thus, our assumption of average yield loss to BGYMV is 25 %, which is considerably less than the level (50%) found in experimental trials of RVs and TVs under severe BGYMV pressure. Multiplying the assumed yield loss levels by their corresponding frequencies (Table 11), we assume that the RVs give a 20% yield gain (yield loss averted) over TVs, on average.

For Catrachita, a non-resistant MV, we assume a 10% yield gain, based on the survey results from Martel (1995) and experimental trials[17]. DICTA 113 and DICTA 122 are not included in this analysis, given their negligible levels of adoption (0.5% and 0.0%, respectively).

Table 11. Model Assumptions of BGYMV Frequency and Yield Losses, Honduras

Assumed Yield Loss to BGYMV[a] for Traditional Varieties	Assumed Frequency of BGYMV Incidence[b]
40 %	1 in 5 years
30 %	1 in 5 years
20 %	1 in 5 years
10 %	1 in 5 years
0 %	1 in 5 years
Expected yield loss for TVs assuming BGYMV incidence = 25 %	Expected yield loss per year for TVs = 20 %

[a] Assumed yield loss values based on Zamorano and DICTA experimental trials which in which non-resistant TVs lost 0 to 50% yield in comparison with RVs.
[b] Assumed frequencies based on results from CRSP/PROFRIJOL Farmer Survey, 2001

Price Discounts Further, we assume that Dorado and Don Silvio growers receive a 16% price discount, compared with TVs, based upon a yearly average of our *primera* and *postrera* 2000

both) the disease was most frequent, and how many times it had come in the past 5 years. Half the respondents claimed that BGYMV was a problem in both seasons, and 17 % said only in the primera. The average incidence frequency reported by the respondents was four out of five years. Therefore, we assume that BGYMV is a problem in both seasons, although we do sensitivity analysis on this assumption.

[17] Catrachita average prices in our survey appear to be a local phenomenon, as were its yields. In the two villages in our sample in which Catrachita was used, its average price was equivalent to that of TVs in these villages. Yet, because the price level in these villages is higher than in the sample at-large (Table 10), Catrachita appears to have a price premium over TVs.

farm-level price data. We assume a 7% discount for Tio Canela, based on the yearly 2000 price average, as well as the wholesaler discount. For Catrachita, we assume a price discount of 5%.

Given these price and yield assumptions, the fact that Dorado is still grown by many respondents--with Tio Canela available--can be explained in various ways, including farmers' reluctance to switch varieties; a lack of information and/or access to Tio Canela (it was released in 1997 and there is no public extension service), or perhaps specific agronomic characteristics of Tio Canela that are not appropriate or preferred by farmers who current plant Dorado. Nevertheless, the adoption of Dorado appears to have peaked a few years ago, while the adoption rate of Tio Canela is increasing rapidly.

Incremental Costs For the following benefit-cost analysis, we assume that adopters of MVs incur no incremental costs per hectare. The vast majority of adopters obtained their seed from other farmers (uncertified seed), and even if they pay their neighbor a markup above what they would pay for a TV, the cost of seed is not a large proportion of input costs. Although it is possible that RV adopters may be able to save both labor and input costs from reduced insecticide applications, the farm-level health and financial benefits from reduced insecticide use associated with RV adoption are not considered.

6.5 Aggregate Benefits

Adoption Curves Given the evidence--from both this survey and that of Martel (1993)-- that adoption rates and ceilings differ by administrative region, we use data points from the 1993 and 2001 surveys to fit a logistic curve for each of the four varieties, by season and by region (16 curves) from their respective year of release until 2010 (Appendix, Figure 2). The curves delineate "area" rates of adoption by season and by region, rather than farmer adoption rates. The area adoption curves are quite similar to "farmer" adoption curves, given the relative homogeneity of farm-size in the sample.

Adoption by Variety For *Tio Canela*, we have only 4 years of farmer adoption behavior, as the variety was released in 1997. However, it is clear that it is quickly being adopted--both by former growers of Dorado or Don Silvio and by TV users. Therefore, we assume that its potential ceiling is equal to the area planted to Dorado in 1998 (37% in the *primera*, 31% in the *postrera* for the Mideast; and 34% in the *primera*, 22% in the *postrera* for the Northeast)[18].

[18] Because of the wide-spread distribution of Dorado, Don Silvio and Tio Canela seed in 1999 by the USAID Post-Mitch Agriculture Rehabilitation project, 1998 is chosen as a year more

Thus, we project that Tio Canela will eventually replace Dorado and Don Silvio, given Tio Canela's price and yield advantage, relative to both of these varieties[19].

For *Don Silvio*, we assume that the 2000 adoption level of 4% (average of *primera* and *postrera* 2000) is its ceiling in each region, and that growers gradually disadopt (switching to Tio Canela) until the rate falls to 0% in 2010. We assume that the Catrachita ceiling is 12% in the Mideast and 7% in the Northeast, and we assume that Catrachita is disadopted to 0% in the Mideast by 2010, and to 0% in the Northeast by 2000 (as indicated by the 2000 survey)[20].

Economic Surplus Model A small open-economy model is used (Alston, Norton and Pardy, 1995), which estimates the downward shift of the supply curve. In this model, the supply curve is linear, and its shift is parallel, which is reasonable given that MV adoption is scale-neutral. The yield gain associated with MVs is accounted for at the farm-level. For simplicity, the MV price discount is modeled as a percentage increase in input costs per hectare. Thus, the price discount is included in the calculation of the supply shift parameter. No market price effects are assumed in this model, as incremental volumes of production are assumed to be exported (El Salvador imports Honduran beans regularly). The choice between an open- or closed-economy model of this type typically has a small effect on the total surplus generated.

The discount rate is assumed to be 10%, and the supply elasticity 0.7, given that the short-run and intermediate supply responses of a subsistence crop are generally assumed to be inelastic. The model also uses historic data on bean production by season and region from 1987-1999 (SAG, 1999). We assume that future (2000-2010) production levels by season and region will be the same as the 1996-1999 average levels (excluding postrera 1998 due to Hurricane Mitch). The bean price series used for economic analysis is Honduras farmgate price from 1987-2010. We use the farmgate price series rather than an import parity price given that the Mideast and Northeast regions are close to the main export market (El Salvador and Nicaragua, a shadow

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representative of the typical demand for resistant varieties.

[19] While it is possible that the expected release of Milenio or another future Zamorano/DICTA variety could displace Tio Canela in the future, including Milenio's benefits and research costs in our analysis would simply increase the incremental benefits that in this model accrue to Tio Canela, as Mileno's market price appears to be even more favorable than that of Tio Canela.

[20] Adoption rates for Catrachita in 1993 were 27% in the Mideast and 16% in the Northeast (Martel, 1995). However, we assume that "area" adoption rates for Catrachita may be lower, given that Catrachita is primarily used by highland farmers, and that Martel's sample was 50% from "hilly" areas. Our sample was selected based upon area, and was not stratified by topography.

market, as per Martel), thus the farmgate price is the best approximation to export opportunities. In addition, the IPP series (U.S. pintos from Colorado) brought to the farmgate is similar to farmgate prices (when adjusting for assumed minimum 20% consumer premiums for preferred characteristics of domestic beans).

6.6 Research Costs

Each of the improved varieties were developed, tested, released, and extended by Zamorano and DICTA. Costs associated with the development of the six MVs in our analysis begin in 1982 (the initial developmental stages of Catrachita) and continue to 1997 (when Tio Canela was released).

Zamorano The Bean/Cowpea CRSP supports the Zamorano bean program's research activities, as well as training. This analysis assumes that 60% of the CRSP support to the Zamorano bean program budget and 60% of training investments during the 1986-1997 period can be attributed to the development and dissemination of the MVs. Financial support from PROFRIJOL to Zamorano's bean program is included at the 100% level. Zamorano's contribution to the bean program includes the fixed costs of buildings and the director's salary (who also teaches at EAP). We include 50% of the director's salary.

DICTA DICTA's expenditures on bean research were generated using DICTA regional budget totals. Of the total budget for the Danli experiment station (for all crops), we assume that 50% supported research and extension on beans, while the respective bean proportion at the Olancho station is assumed to be 14%[21]. Of these DICTA *bean* research costs, 100% is assumed to be related to the development and extension of the improved varieties. DICTA's national bean program began its work with Catrachita and Dorado in multi-locational trials in 1986 and 1987. However, as we have no cost data to account for CIAT's role in the Cross, Nursery, and On-Station Trial stages of the development of these two varieties (from 1982/83 to 1985/86), we extend DICTA's costs back to 1982. Financial support from PROFRIJOL to DICTA is also included at the 100% level.

Other Potential Costs Other potential costs which are not included at present include CIAT's role in crossing Dorado and Catrachita (discussed above). In addition, the USAID Post-Mitch seed multiplication and distribution program likely played a role in facilitating adoption of

[21] Share assumption made by Danilo Escoto, the current DICTA bean breeder and the only DICTA manager with more than 5 years in DICTA.

Dorado, Don Silvio and Tio Canela in 1999 and 2000. However, it is difficult to estimate the influence of this project for two reasons. First, the project records for USAID's seed distribution in *primera* and *postrera* 1999 only indicate how much seed each NGO received, and the general location of each NGO's pre-Mitch agricultural activities–there is no information on how much seed was delivered to each region. Thus, we don't know precisely how much seed was delivered by NGOs to the Mideast and Northeast regions, although it is clear that the general location of the NGOs' operations prior to Mitch placed a smaller emphasis on these two regions. Secondly, while only 9 % of our sample received seed directly from an NGO following Mitch, we don't know how many other farmers may have received seed indirectly in 2000 from the initial recipients of the Post-Mitch seed distribution program.

6.7 Rate of Return to Bean Research

Assuming that BGYMV causes losses to TVs during both the primera and postrera seasons, the economic rate of return bean research in Honduras during the period 1982-2010 is 40 %, and the Net Present Value is US$50 million. Assuming that BGYMV causes losses to TVs only during the postrera seasons, the economic rate of return bean research in Honduras during the period 1982-2010 is 35 %, and the Net Present Value is US$32.5 million. More formal sensitivity analysis is forthcoming, although as we have started with rather low benefit estimates and high costs (and a conservative estimate of supply elasticity), the ROR is not likely to fall under more scrutiny of our base assumptions.

This analysis provides strong evidence that the return to bean research in Honduras has been profitable on aggregate. We have assumed minimal benefits: at the farm-level, we are assuming a 20% average yield increase for resistant MVs, and a 10% yield increase for Catrachita. The value of these yield gains are dampened by the 5 to 16% price discounts for MVs. In addition, we have assumed near-maximum variable costs of bean varietal development and dissemination. Furthermore, although data are not available to document the spillover impact in non-surveyed areas, key informants report that many farmers in other regions of Honduras, as well as in El Salvador and Nicaragua, have adopted both Tio Canella and Dorado. Finally, this analysis charges Zamorano's research expenditures against the MVs that have been released in Honduras. However, during the period considered, Zamorano developed additional varieties (Bribri in Costa Rica). In this analysis, the cost of developing these varieties is charged to the varieties released in Honduras, and the benefits associated with their release is not considered, due to the

unavailability of data.

7. Conclusion

In the late-1980s and early-1990s, Honduran bean scientists recognized the need to introduce virus resistance into improved varieties. Despite the lack of a public extension service or a large scale seed dissemination initiative, adoption of improved varieties is widespread across the two surveyed regions. Given the price discount of these MVs, adopters clearly must be receiving benefits in the form of higher and/or more stable yields. However, the incremental yield of resistant MVs is difficult to estimate from survey data, given selection bias. Furthermore, even in the valleys of Honduras, beans are grown predominantly by farmers with less than 3 hectares of land, and previous research has demonstrated that adoption of Dorado and Catrachita is scale-neutral by market orientation and by farm size (Martel, 1995).

In looking to the future, Zamorano is expanding its bean research program to focus more effort on identifying sources of drought and heat tolerance, in addition disease resistance. Since the mid-1990s, Zamorano's bean research program has actively collaborated with social scientists in an effort to identify social and economic constraints to adoption. Partly in response to Martel's study (1995) that document the market price discount for MVs, the bean research team has given increased priority to improving the quality (color) of its releases–as evidenced by the forthcoming release of Milenio.

Additional analysis of the 2000 CRSP/PROFRIJOL Bean Farmer survey is forthcoming, possibly combining this survey data with the BGYMV incidence maps produced by Johnson and Klass (1999). Further priority research includes *ex ante* research on beans in Honduras, focused on identifying production constraints in terms of their geographic and demographic spread, their frequency, and the economic and nutritional value of production losses, given the incidence of the constraint. Finally, analysis of the institutional constraints to the development of a more formal Honduran bean seed system is recommended.

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Appendix

Table A-1: Farmer Bean Seed Source, Modern Varieties, 2001		
Seed Source	**Seed (Germplasm) Planted in Postrera 2000 (%)**	**Original Source of this Variety (%)**
Farmer-Saved Seed	59	na
Neighbors	27	57
Traders	6	10
DICTA / SAG	0	16
Zamorano	3	3
CIAT Seeds of Hope	0	2
NGO	0	0
Input Dealer	2	4
Local Market	0	3
Artisan Seed	0	0
Other	2	5
Source: CRSP/PROFRIJOL Farmer Survey, 2001		

Fig. 2: Projected MV Bean Adoption
Mideast & Northeast Honduras