Economic Losses Associated with *Zabrotes subfasciatus* (Boheman) (Coleoptera: Bruchidae) and *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae) Infestations of Stored Dry Red Beans (*Phaseolus vulgaris* L.) in Southeastern Honduras

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Abstract. A survey in Honduras evaluated the postharvest effects of *Zabrotes subfasciatus* and *Acanthoscelides obtectus* on red beans in three southeastern Honduran communities. Weight losses caused by these bruchids and other factors during 1991 after seven months of storage averaged 8.5% in dry beans stored by small-scale farmers. Storage losses caused by insects and factors other than insects were estimated at 6.9% and 1.6% respectively. Postharvest weight losses during 1993 reached 6.6%. Field losses and storage losses were 2.4% and 4.2%, respectively. Bruchids accounted for 24.5% of the combined losses. Applying the market value of beans at time of scarcity, the postharvest monetary loss (1993 value) reached US $14.80 to US $20.10 per farmer. This loss represented 2.9 to 3.9% of the annual per capita income. Farmers could have financed 14.2 to 19.2% of production costs of their bean crop if they were able to avoid these losses. The value of postharvest losses would have allowed the farmer to purchase enough dry beans (22.5 kg) to feed an average family for 49 days. When extrapolating the value of all postharvest losses, monetary losses nationwide reached US $2.6 to 3.5 million per year. Monetary losses caused by insects were estimated at US $670,500 to 908,900 during 1993.

Key words: Field losses, monetary loss, subsistence farmers, weight loss.

Resumen. Se evaluaron los efectos poscosecha de *Zabrotes subfasciatus* y *Acanthoscelides obtectus* en frijol rojo almacenado en tres comunidades del sur-este de Honduras. En 1991 las pérdidas de peso causadas por estos bruquidos y otros factores a productores de pequeña escala en siete meses de almacenamiento alcanzaron 8.5%. Las pérdidas de almacenamiento causadas por insectos fueron 6.9% y por otros factores fueron 1.6%. Durante 1993 las pérdidas en poscosecha alcanzaron 6.6%. Las pérdidas de campo y de almacén fueron 2.4% y 4.2%, respectivamente. Los bruquidos fueron responsables por el 24.5% de la suma de ambas pérdidas. Al aplicar los precios de mercado de frijoles en tiempo de escasez (precio de 1993), la pérdida monetaria alcanzó de 14.80 a 20.10 dólares norteamericanos por productor. Esta pérdida representó entre el 2.9 y 3.9% de su ingreso per cápita anual. Si los productores hubieran evitado estas pérdidas, hubieran podido financiar entre 14.2 y 19.2% de los costos de producción del cultivo. El valor monetario de las pérdidas poscosecha les hubiera permitido comprar suficiente frijoles (22.5 kg) para alimentar a su familia por 49 días. Al extrapolar el valor de todas las pérdidas poscosecha de frijol, las pérdidas monetarias a nivel nacional alcanzaron de 2.6 a 3.5 millones de dólares por año. Las pérdidas monetarias en 1993 causadas por insectos se estimaron entre 670,500 y 908,900 dólares norteamericanos.

Palabras clave: Pérdida de campo, pérdidas de peso, pérdida monetaria, productores de subsistencia

Introduction

In most developing countries rural populations live in relatively isolated communities, self-reliant in terms of food grain production. The standard of living of a rural community depends not only upon the range of foods grown and the capacity to produce quantitatively, but also upon the facilities for efficient handling, drying, storage, and marketing (Hall 1970).

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Unfavorable climatic conditions, higher cost of inputs, limited use of genetically improved varieties, deficient marketing, insufficient technical assistance, high incidence of pests and inadequate postharvest management are the factors most relevant for production deficits experienced by these farmers.

In Honduras, the agricultural sector is of major importance to the economy. Of the total land area, 32% (3.6 million ha) is comprised of forests and woodlands (FAO 1991). Cereal grains and legumes constitute the main source of food for the majority of the population and of employment for the rural labor force.

Red beans (*Phaseolus vulgaris* L.), the most extensively cultivated grain legume in the country, represent the main source of protein for the rural human population. In addition, dry bean consumption complements the amino acid pattern of cereal staples and serves as an important source of energy (Quentin *et al.* 1991).

During the early 1990's, an average of 64,046 hectares was planted to dry beans, with country-wide yields estimated at 46,684 metric tons. Sixty–seven percent of this production came from three regions, the northeastern (28%), the southeastern (21%), and the western (18%). Yields of dry beans during 1976-1991 averaged 695 kg/ha. However, per capita consumption during 1991 was estimated at 38 g/person/day compared to 40 g/person/day in 1976. An annual average of 455 metric tons of dry beans was imported during 1976-1987 to meet the domestic demand (IICA 1988).

A gain in average grain consumption in a country typically means an improvement in welfare of the population. Given the socio–economic conditions of subsistence farmers, any grain loss experienced can have a significant economic impact on the standard of living (Brown 1991).

The bruchids *Acanthoscelides obtectus* (Say) (Common bean weevil) and *Zabrotes subfasciatus* (Boheman) (Mexican bean weevil) are the two most important arthropod species feeding on stored dry beans in Honduras (Hoppe 1986). *A. obtectus* frequently infests beans in the field, as well as in storage. *Z. subfasciatus* is more commonly encountered in storage and does not attack beans in undamaged pods (Van Schoonhoven 1976, Pajni 1986). Inadequate postharvest management and some traditional storage practices implemented on small farms facilitate survival of these storage pests.

In Honduras, per capita income averaged $516 US (US Department of State 1992). Most farmers lack cash at harvest time. At that moment, despite the seasonally low price of the grain, they are forced to sell a significant portion (about 2/3) of their harvest to obtain cash to fulfill certain basic needs (payment of loans, medical care, supplementary foods, etc.). In so doing, they immediately experience considerable monetary loss caused by inconvenient marketing.

Our objective was to complete a preliminary survey of small farms in selected communities of southeastern Honduras, to examine factors associated with weight losses caused by *A. obtectus* and *Z. subfasciatus* infestations, to express in monetary terms the storage weight losses caused by these bruchid species, and estimate the direct economic impact of storage weight losses on small and medium-scale farmers of southeastern Honduras during the time interval studied.

Materials and Methods

The surveyed area included the township of Moroceli, located at 14° 08' North Latitude and 86° 53' West Longitude at an average altitude of 700 masl. This area has an equatorial climate with an annual rainfall averaging 1175 mm, most of which is distributed between May and December. The surveyed region encompasses a surface area of 332 km^2. In these communities dry beans are commonly produced and farmers during the early 1990s typically employed traditional postharvest practices. After harvest, the beans were left in the field to dry and were treated with aluminum phosphide or natural products such as plant materials, ash or lime.

Farmers were selected according to recommendations by extension personnel with the Department of Rural Development (DDR) of Escuela Agrícola Panamericana (EAP) in El Zamorano, Honduras. Farmers surveyed met three basic requirements. They had to have sufficient dry beans in stock to allow two sampling visits spaced four weeks apart for the 1991 study, and four sampling visits for the 1993 study. Cooperators had to cultivate between 1 to 10 ha of dry beans and be willing to collaborate with the scientists conducting the survey. In the 1991 study, a total of 23 farmers were selected, 5 from Moroceli, 5 from El Suyate, and 13 from Potrero Grande. In the 1993 study, a total of 29 farmers were included, 9 from Llano del Tigre, 5 from El Suyate, and 15 from Potrero Grande. It has been observed over the years that by May and June, most families had consumed all their stored beans. To meet their consumption needs, farmers bought additional beans from small local grocery stores. It was difficult to find farmers possessing enough of their own product to survey losses after May. Surveying an unequal number of farmers per village was necessary.

An initial questionnaire about management practices at harvest, drying, and threshing was completed for each farmer. Field losses were assessed at harvest in December of 1992. The initial sample was taken to determine losses occurring after harvest but before the storage period of January to May 1993. A sample consisting of 1 kg of red beans per farmer was collected from harvested beans still lying in the field to dry. Purchases of dry beans were made to compensate farmers for samples removed.

The samples were sequestered in labeled plastic bags and then returned to the laboratory facilities of the International Seed and Grain Science Center (CITESGRAN) of EAP for analysis. Three subsamples per sample were created using a Boerner divider. Each subsample was analyzed independently. Field loss per farmer was determined as the average assessment of 500 kernels randomly obtained from each 0.3 kg subsample. Damaged and undamaged kernels were separately counted and weighed. Average weights of individual undamaged and damaged kernels were obtained. The potential weight of samples was estimated by multiplying 500 times the average weight of individual undamaged kernels. Then, causes of damage were determined and the damaged kernels were separated into categories of damage. To calculate percent sample loss, potential weight was compared to actual weight. The parameters determined in the field sample included mean weight of sound kernels, mean weight of damaged kernels, moisture content, germination, hidden infestation of bruchids, and total weight loss. Other causes of weight loss included field fungi, germination, mechanical damage, and field insects. At this point, assessment of weight losses caused by storage insects was not necessary because visible damage had not occurred.

Equipment needed for analysis of field samples included sieves (0.48 cm), pans, Boerner divider, precision scales, a moisture meter (Motomco), glass jars, forceps, magnifying glass, labels, blades, germination paper, and seed counters. Before analysis, a subsample of 100 g from each storage sample was placed in 0.5 L glass jars to assess hidden insect infestations.

The initial storage survey was conducted during the last two months of the late-season storage period (late May to end of June, 1991) and the full study was completed during the storage period following the late planting season (mid September to mid October) of 1992. During the late planting season, beans are the most widely cultivated food crop. During this season, beans are harvested in December. Thus, the storage period started by the end of December 1992 and ended in May of 1993. Relevant data on bean storage practices and usage were recorded every time a sample was collected.

Storage units of the farmers in this study were sampled on a monthly basis. Sampling in both studies consisted of removing 0.5 kg samples of beans from the storage unit farmers maintained for consumption. Purchases of replacement dry beans were also made to compensate farmers for the quantity removed. To obtain a representative sample, two types of hollow spears were employed. A 30 cm aluminum spear was inserted into different parts of each sack. Sacks (typically 100 kg in capacity) were not always filled to capacity. A 1.0 m long aluminum spear with compartments was used to obtained samples of grain from the center of the sacks. To sample metal barrels only the long spear was used. Each sample was composed of portions taken from different parts of the storage unit (top, middle, and bottom). Samples were sequestered in labeled plastic bags, which were returned to the laboratory for analysis. The samples were analyzed in the laboratory of CITESGRAN.

Laboratory processing of all samples involved visual inspection of each bean kernel for signs of insect damage and other factors causing damage. Analysis of samples allowed determination of levels and causes of damage and losses based on the relation between real and potential weight of the kernels examined. Because the analysis of samples took more than one day, the plastic bags containing the samples were stored in a freezer to stop insect feeding activity. By using a Boerner divider, 500 kernels were randomly obtained from the 0.5 kg sample. Damaged and undamaged kernels were separately counted and weighed, and then the causes of damage were determined and separated into two categories: insects and other causes. Exit holes in the kernel were signs of insect damage. Average weights of individual undamaged and damaged kernels were calculated. The potential (viz., original) weight of samples was estimated by multiplying 500 times the average weight of individual undamaged kernels. To calculate percent sample loss, potential weight was compared to actual weight. To calculate sample loss attributed to insects the same procedure was followed, but only insect damaged kernels were considered. Other variables analyzed included moisture content and germination. Moisture content of the sample was obtained using a Motomco moisture meter (model 919a).

The loss assessment method used to calculate storage weight losses was modified from the methodology for maize developed in 1982 by a joint Honduran-Swiss Post-Harvest Unit (Raboud *et al.* 1984). This method uses monthly sampling as a tool to document deterioration occurring within stored grain. Samples were taken as they would have been by the person preparing the maize for consumption.

Some changes were made to clarify how weight losses caused by insects were calculated. The original approach distinguished between the terms damage and loss. Damage was any physical alteration of the kernels and loss refers to total kernels damaged minus the kernels that despite their physical damage can be used for consumption (recoverable). In the modified analysis of insect damaged kernels, the concept of recoverable grains was not taken into account because the weight loss already had occurred even if the damaged kernels were consumed. In addition, insect damaged seeds in our samples were so highly infested by two bruchid species, that none could be considered suitable for human consumption. Percent total damage, total loss, percent total loss caused by storage insects, losses caused by other factors (grouped) were calculated using formulae contained in the modified loss assessment methodology. The storage loss caused by insect feeding was not separated by species causing the damage; it was expressed only as losses attributed to storage bruchids in general. A representative sample was taken from the entire storage unit instead of the portion reserved for consumption.

To express postharvest weight losses in monetary terms, the following data were used: weight loss assessment, monthly records of grain quantity, and monthly grain market value. Market values were applied to realize weight loss using two approaches. In the first, the market value of dry beans during the months of May through July was applied to postharvest weight losses. During these months most farmers do not have any grain left in storage, thus, they buy it at higher prices to meet consumption needs. In the second approach, monthly market values were applied to monthly storage loss to calculate the cumulative monetary value of weight losses.

Data were analyzed using General Linear Models-Least Significant Means Test ($\underline{P} < 0.05$ [SAS Institute] 1990). Data reported as percentages were transformed using the formula arcsine $\sqrt{x}$. Analyses were performed on the transformed data; but values in tables represent the untransformed means.

Results and Discussion

Results of the 1991 survey indicated that an average of 82.6% of the 23 farmers surveyed used 100 kg sacks as their primary storage unit. Only 17.4% used 175 kg capacity metal barrels to store beans. Farmers keeping dry beans outside the house used barrels as their storage unit. All farmers using sacks kept their storage units inside the house. About 78.3% of the farmers surveyed used phosphine tablets to control bruchids. The rest used a common traditional control measure (plant residues, ash and lime mixed with the seeds at inconsistent doses). Four different varieties of dry beans were used by the farmers in this survey. In some cases, farmers plant more than one variety but they designate only a specific variety for storage. The varieties included Zamorano, Catrachita, Dorado, and Criollo (not a true variety but a mixture of genetic material compiled through perennial seed saving practices). Usage of these varieties was not equally distributed among all farmers under study.

Storage weight losses in 1991 were caused by insects and other factors (grouped). The community of Moroceli experienced the highest storage loss, 19.8% (Table 1). This level was significantly different from the storage loss observed at either El Suyate (4.0%) or Potrero Grande (1.6%) ($P \leq 0.05$). Percent storage losses at El Suyate and Potrero Grande did not significantly differ ($P \geq 0.05$). Overall estimated mean late storage season losses for the three communities surveyed reached 8.5%.

During 1991, the insect species present in the samples were identified as *Z. subfasciatus*, and *A. obtectus*. In only four of 43 samples were these species found independently infesting stored dry bean seeds. In the remaining 39 samples the two species jointly infested the stored beans. When they were present in the same sample, *Z. subfasciatus* outnumbered *A. obtectus*. Overall percent losses caused by these insect species to dry beans stored under farm conditions in Moroceli, El Suyate, and Potrero Grande are shown in Table 1. The community of Moroceli experienced the highest storage loss attributed to insects (18.6%). The loss in Moroceli was significantly different from storage losses caused by insects in El Suyate and Potrero Grande ($P \leq 0.05$).

Catrachita had the lowest losses caused by insects (Table 2). At 1.4 %, the damage was not significantly different from damage to Zamorano (8.2%) or Criollo (8.0%) ($P \geq 0.05$), but was significantly less than that experienced by Dorado (9.9%) ($P \leq 0.05$). No significant differences ($P \geq 0.05$) in percentage weight lost to insects were experienced by varieties Zamorano, Dorado and Criollo types.

Storage losses caused by insects within varieties were compared to storage losses caused by other factors (Table 2). Storage losses caused by insects as a proportion of the total storage loss for each variety represented more than 80% of the total storage loss for all varieties except Catrachita (45.2%).

Overall means of percent storage loss caused by other factors (including field fungi, field insects, storage fungi, mechanical damage, and germinated kernels) at Moroceli, El Suyate, and Potrero Grande (Table 1) were not significantly different ($P \geq 0.05$). The storage losses caused by non-insect factors sustained by each variety, did not differ significantly ($P \geq 0.05$) (Table 2) and did not exceed 2.0% of total weight loss.

The description of the dry bean postharvest system in the communities surveyed during 1993 was obtained through baseline and monthly questionnaires. Table 3 contains a summary of the most relevant information on productivity, quantity harvested, and proportion of the production sold immediately after harvest or stored for consumption. According to all farmers surveyed, yields in the region were lower during the 1992 late planting season because rainfall was inadequate during the crop vegetative and bean fill stage. Quantity harvested (kg), percent sold immediately after harvest, and area of land planted with dry beans (hectares) in Potrero Grande and El Suyate did not differ significantly ($P \geq 0.05$). Farmers of Llano del Tigre harvested a smaller quantity per individual because they planted a smaller average area of land. Thus, they sold a significantly smaller quantity of beans immediately after harvest ($P \leq 0.05$). However, the quantity stored per family was not significantly different from the other two communities ($P \geq 0.05$). Yield (kg/hectare) in all villages did not differ significantly ($P \geq 0.05$). Overall percentage of the crop sold averaged 63.2% in the communities surveyed. Marketing was usually done at the local level. Similar results were obtained by Chavez 2001 and Borja 2001 in two studies designed to evaluate weight and monetary loss in two storage systems (800 kg capacity metal bins and 100 kg capacity sacks) conducted in the same region.

In the 1993 survey, 100 kg capacity sacks were the most frequently encountered container used for storage. These storage units were maintained inside the house. Some farmers employed 175 kg metal barrels kept either inside or outside the house. In Potrero Grande, all farmers used sacks to store their beans. In Llano del Tigre, 33% of farmers preferred metal barrels. In El Suyate, only one farmer (20%) stored his grain in a metal barrel.

Table 1. Percent[a] storage weight loss, storage loss caused by bruchids, and storage loss caused by other factors[b] to farm stored dry red beans harvested during the 1990 late planting season (postrera)[c] in three communities of southeastern Honduras.

Community	No. of farmers	% Weight loss ± S.E.	% Weight loss due to insects ± S.E.	% Storage loss by other factors ± S.E.
Morocelí	3	19.8 ±2.4 A	18.6 ±3.0 aA	1.2 ±0.7 Ab
El Suyate	6	4.0 ±2.3 B	2.1 ±2.4 aB	1.9 ±0.5 Aa
Potrero Grande	14	1.6 ±1.6 B	-0.1 ±1.6 aB	1.8 ±0.3 Aa
Average		8.5	6.9	1.6

[a] Means followed by different upper case letters in each column and means followed by different lower case letters within rows are significantly different ($P \leq 0.05$).
[b] Includes field fungi, field insects, storage fungi, mechanical damage, and germinated kernels.
[c] Beans were planted in October, 1990, harvested in December, 1990, and stored from January through July 1991.

Table 2. Percent[a] storage weight loss, storage loss caused by bruchids and other factors[b] to four different dry red bean varieties used by subsistence farmers in southeastern Honduras during 1991.

Varieties	No. of farmers	Total storage loss (%)	Storage loss by insects (%)	Loss by insects as a % of total loss	Storage loss by other factors[c] (%)	Loss by other as a % of total loss
Catrachita	4	3.1 ±2.8 A	1.4 ±2.9 Aa	45.16 A	1.7 ±0.6 Aa	54.84 B
"Criollo"[c]	4	9.4 ±2.2 AB	8.0 ±2.3 ABa	84.32 B	1.5 ±0.5 Ab	15.68 A
Zamorano	9	9.5 ±2.7 AB	8.2 ±2.8 ABa	86.54 B	1.4 ±0.6 Ab	14.61 A
Dorado	6	11.8 ±2.0 B	9.9 ±2.1 aB	83.58 B	2.0 ±0.5 Ab	16.52 A

[a] Means followed by different upper case letters in each column and lower case letters within rows are significantly different ($P \leq 0.05$).
[b] Includes field fungi, field insects, storage fungi, mechanical damage, and germinated kernels.
[c] A mixture of genetic material compiled through perennial seed saving practices.

Table 3. Average area planted, quantity harvested, yield, quantity sold after harvest, and quantity of dry red beans placed in storage per farmer from three southeastern Honduran communities during the 1992 production period and 1993 storage period respectively[a]

Community	Cultivated Area (ha)	Quantity harvested (kg)	Yield (kg/ha)	Quantity sold		Quantity stored	
				kg	%	kg	%
Potrero Grande	3.5 ab	1089.3 ab	311.5 a	865.9 b	79.5 b	223.5 a	20.5 a
Llano del Tigre	1.4 a	489.9 a	377.2 a	166.7 a	34.0 a	323.2 a	66.0 b
El Suyate	4.2 b	1399.9 b	346.8 a	1063.5 b	76.0 b	336.3 a	24.0 a
Overall average	3.0	993.0	345.2	698.67	63.2	294.3	36.8

[a] Means in each column followed by different letters are significantly different ($P \leq 0.05$).

Farmers of Potrero Grande did not undertake any insect prevention measures at the beginning of the storage period. In Llano del Tigre, 45% treated their grain with a fumigant at the beginning of storage. In all communities surveyed, whenever farmers treated grain with a fumigant, they employed a dose of one 3 g tablet of PH_3 (equal to 1 g of phosphine) per 100 kg of dry beans. Fumigations were carried out in the house in sacks without hermetic sealing or taking recommended safety precautions, therefore farmers and their families were at high risk since phosphine is a deadly gas. This method of treating possibly promotes insect resistance to phosphine. Also, money is wasted on partially or non-effective control. However, farmers believe that phosphine was a good control method because they could see dead adults in and around the house. In El Suyate, all farmers surveyed implemented some kind of control measure at the beginning of the storage period. Most of them (80%) used phosphine and 20% employed some other type of non-chemical control measure, typically an inconsistent dose of ash mixed with the grain. At the correct dosage, ash can be an effective control measure for bruchids (Rodriguez 1992).

The market value of dry red beans changed through time (Table 4). The price of dry beans after harvest during December was at its lowest. Market value increased as consumption made dry beans less available. During a 4-month period the market value doubled from US$20.02 per 45.4 kg to US$40.55 for the same quantity. The highest market value coincided with the least quantity of dry beans remaining in storage. By the end of April, most farmers only had enough beans to supply seed for the next planting season. For consumption they had to purchase beans through the local market.

An overall mean of 6.6% postharvest weight losses (field losses = 2.4% + storage losses = 4.2%) was experienced by farmers from the three communities surveyed in 1993 (Table 5). Total quantity wasted by postharvest losses in the three communities averaged 16.7 kg (Table 6).

Postharvest field loss contributed 44.2% of the overall average postharvest loss (Table 7). Data indicated that field loss in El Suyate was lower than experienced by farmers in the other two communities. However, it did not differ from field losses sustained by dry beans harvested near Potrero Grande ($P \geq 0.05$) (Table 5). The overall average percent of dry beans wasted or left in the field during harvest and lost before storage reached 2.3%, which is equivalent to a weight loss of 6.9 kg per farmer (Table 6).

Table 4. Changes in the market value (in US$) per 45.45 kg[a] through the storage period (1993) in three selected southeastern Honduran communities.

Community	December	January	February	March	April	May	June	July
Potero Grande	20.00	21.67	26.67	31.67	33.33	41.67	41.67	56.67
Llano del Tigre	20.00	20.00	25.00	30.00	31.67	40.00	40.00	54.17
El Suyate	20.00	20.00	25.00	30.00	31.67	40.00	40.00	54.17
Mean/village	20.00	20.55	25.55	30.55	32.22	40.55	40.55	55.00

[a] 45.45 kg is equivalent to 1 Honduran quintal (100 lb) which is the common measure employed when marketing grain in rural areas.

Table 5. Factors causing weight losses during 4 months of storage of dry red beans by selected farmers from three southeastern Honduran communities during 1993.

Community	Average storage loss/ farmer (%)[a]	Weight losses (%)[a]					
		Bruchids	Storage fungi	Germinated	Mechanical damage	Field insects	Field fungi
Potrero Grande	1.80 A	0.40 Ab	0.01 Aa	0.01 Aa	0.30 Ab	0.72 Ac	0.37 Ab
Llano del Tigre	3.72 B	1.62 Bd	0.02 Aa	0.02 Aa	0.98 Cc	1.04 Bc	1.62 Bd
El Suyate	3.97 B	2.04 Bd	0.11 Aa	0.02 Aa	0.66 Bb	0.74 Ab	2.04 Bd
Overall mean/farmer	3.16	1.35	0.30	0.01	0.65	0.83	0.05

[a] Means in each column followed by different upper case letters and means within each row followed by different lower case letters are significantly different ($P \leq 0.05$). Mean separations are based on transformed values (arsine $\sqrt{x}$).

Table 6. Field loss, overall storage loss, and losses caused by storage insects per farmer expressed as a percentage of the total postharvest weight loss experienced by dry beans of selected farmers from three southeastern Honduran communities (1993).

Community	Field[a] loss (%)	Losses during storage[b] (%)		Total storage[c] loss (%)
		Insects	Other factors	
Potrero Grande	59.32	9.10	31.58	40.68
Llano del Tigre	42.41	31.58	26.01	57.59
El Suyate	30.96	28.17	40.87	69.04
Average/farmer	44.23	22.95	32.82	55.77

[a] Calculated from the sample taken in December before storage.
[b] Calculated from storage samples taken every month.
[c] Total storage loss = loss by bruchids + loss by other factors.

Table 7. Average quantity stored and postharvest weight losses per farmer per community after 4 months of storage of dry red beans from three southeastern Honduran communities (1993).

Community[a]	Average quantity stored (kg)	Field loss[b] (kg)	Losses during storage (kg)		Total storage loss (kg)	Average loss/ farmer (kg)
			Insects	Other factors[c]		
Potrero Grande	223.5	5.8	0.9	3.1	4.0	9.8
Llano del Tigre	323.2	8.9	6.6	5.4	12.0	20.9
El Suyate	336.3	6.0	5.5	7.9	13.4	19.3
Overall Mean	294.3	6.9	4.3	5.5	9.8	16.7

[a] Number of farmers sampled per community: Potrero Grande 15, Llano del Tigre 9, and El Suyate 5.
[b] Calculated from the sample taken in December before storage.
[c] Includes field fungi, germinated beans, mechanical damage, field insects, and storage fungi.

Weight losses during storage contributed 55.8% of the total postharvest loss (Table 6). Storage losses in Potrero Grande were significantly lower than experienced by the other two communities ($P \leq 0.05$). Storage losses experienced by El Suyate and Llano del Tigre did not differ statistically ($P \geq 0.05$). The percent of dry beans lost during the storage period reached an overall average of 4% (Table 5), which is equivalent to 9.8 kg per farmer (Table 7).

Storage losses caused by bruchid feeding were significantly lower in Potrero Grande ($P \leq 0.05$) (Table 5). The overall mean weight loss caused by these insects in the three communities surveyed reached 1.35%. Storage insects contributed 23.0% of the total postharvest loss (Table 7). The equivalent average quantity of dry beans wasted by insect attack in these communities was 4.3 kg per farmer (Table 6).

Other factors included field fungi, germinated kernels, mechanically damaged kernels, storage fungi, and insects attacking the seed in the field. Storage losses caused by other factors contributed 32.8% of the total postharvest loss (Table 6). The overall average quantity of dry beans lost by the other factors category amounted to 5.5 kg per family (Table 7). Mechanically damaged kernels and seeds damaged by field insects were the most important. Montoya (2001) obtained similar results and validated many of the findings of this study.

Table 8 includes information on monetary loss sustained by farmers living in the three communities surveyed. Market values during the months of scarcity, May and July, were applied to the weight losses experienced. Production costs (US$90.00 per ha) for the southeastern region, which were used to estimate negative economic effects of postharvest losses, were reported by Seccion de Gestion Rural of the DDR of EAP (1993).

The reason why storage losses in the 1993 study were lower in Potrero Grande may be attributed to the more integrated storage system employed by farmers of this community. This community is better organized that the other two because members of the group meet every month to discuss problems and work together to find viable solutions. Better communication characteristically occurs among these farmers. Another factor that may facilitate lower losses in this village is the higher altitude (805 masl). Cooler temperatures may affect the biology of both bruchids. Weight losses in Llano del Tigre and El Suyate were expected to be similar because in these communities there is not enough difference in altitude or temperature. Prevailing weather conditions remained more favorable for insect attack.

In relation to storage losses caused by non-insect factors, the three villages sustained similar weight losses. In El Suyate, losses by other factors were attributed mainly to storage fungi. The average moisture content of dry bean samples from this community was above that recommended for safe storage levels.

Table 8. Value lost (in US$) through postharvest weight losses to dry beans for selected farmers from three southeastern Honduran communities (1993).

Postharvest weight losses[b]	Overall monetary loss (US$)[a]	
	May	July
Field loss	6.14	8.36
Storage loss	8.68	11.78
Loss by bruchids	3.81	5.19
Loss by other factors	4.87	6.58
Total losses	14.82	20.13

[a] Based on market value during the months of May ($0.92/kg in Potrero Grande, $0.88/kg in Llano del Tigre, and $0.88/kg in El Suyate) and July ($1.25/kg in Potrero Grande, $1.20/kg in Llano del Tigre, and $1.20/kg in El Suyate), 1993.

[b] Field loss was calculated from a sample taken during December 1992 prior to storage. Storage loss = loss by bruchids + loss by others. Loss by other factors include: field fungi, germinated seed, mechanical damage, field insects, and storage fungi. Total losses = field losses + storage losses.

Combining data obtained in this survey (6.8% storage loss) with results on storage loss from the study of Carcamo (1992) (0.4%) in the same region and during the same year was used to estimate overall losses during the primera or early storage season. This process resulted in an estimate of average annual storage losses of 7.2% for subsistence farmers from southeastern Honduras during this period of time.

The average area of land cultivated with dry beans on small- and medium-size farms involved in the 1993 study (3.04 ha) coincided with that reported by Carcamo (1992). This study emphasized postharvest systems of dry beans at the middle-man and subsistence farmer level in a selected area of southeastern Honduras. Another study examined socio-economic factors affecting small and medium farmers from different regions of Honduras (Herrmann 1991). These results implied that, on the average, farmers from the three communities surveyed represented typical small- and medium-scale producers of food grains under conditions of subsistence agriculture within Honduras.

Average yields in Honduras reported by IICA (1988) (686 kg/ha) were higher than those found in this survey (345.16 kg/ha), verifying that smaller quantities of beans were harvested during 1992 in southeastern Honduras. Although dry bean yields were lower, the average quantity of dry beans placed in storage in 1993 (294 kg) slightly exceeded that reported by Hoppe (1986) (100-280 kg). This finding suggests that farmers usually need to buy grain for consumption near the end of the storage period, even though they try to store as much as possible to assure continued consumption until harvest of the early season bean crop occurs during August. Farmers are forced to sell part of their production to intermediaries immediately after harvest primarily because loans obtained to finance production need to be paid. Postharvest costs also need to be satisfied.

In terms of the varieties involved in the 1993 study, it is very difficult to draw specific conclusions because not all varieties were equally distributed among the farmers surveyed. The variety Zamorano predominated in Potrero Grande, Dorado was most commonly grown in Llano del Tigre, and Criollo-types were more heavily cultured in El Suyate. Although within a community many farmers used the same variety, they might handle the stock differently. Farmers growing more than one variety generally stored only one type (Zamorano in Potrero Grande, Dorado in Llano del Tigre and Criollo in El Suyate) because, according to the farmers, these varieties had superior taste and cooking qualities. The others were marketed.

Postharvest weight losses sustained by dry beans (5.5%) are similar to those reported by De Brevé *et al.* in 1984 (4.7%). Storage losses accounted for up to 57% of the total postharvest losses. In the survey conducted by Raboud *et al.* (1984), field loss was more important, accounting for 87% of the total postharvest losses. Schmale *et al.* (2002) noted that 90% of bean samples examined at harvest in Colombia were sparsely infested by *Acanthoscelides obtectus* such that the first weevil generation resulted in 1.6 (Schmale *et al.* 2002) to 2 % damaged seeds (Baier and Webster 1992). Schmale *et al.* (2002) found that the second generation pushed the visible damage level above 5%. Collectively, these findings may imply that small- and medium-scale farmers have adopted better field practices but gave less attention to maintaining grain quality during storage.

Physical losses experienced by subsistence farmers result in variable economic effects. The advantage of concentrating upon physical loss is that direct economic value can be obtained (Greeley 1982). For a farmer in debt and having to purchase grain for consumption during the last months of the storage season, significant negative economic consequences would be expected in at least two ways. First, the corresponding monetary value of the storage weight loss is greater (Schmale et al. 2002, Montoya 2001) and second, the high price paid in the latter months of the storage period for the grain needed for consumption adds to the overall cost. Even so, this estimate of economic loss remains somewhat conservative because nutritional losses were not considered in these calculations.

At the national level, postharvest weight losses can cause negative economic impact for the country because of the magnitude of monetary losses involved, and the amount of grain that the government has to import to supply domestic demand. Considering the average dry bean production spanning 16 years obtained by IICA (1988) and FAO (1991), the cumulative postharvest weight losses documented during this study (5.5%) were equivalent to wasting 2,928 metric tons annually. Assigning the market value prevailing during the months of May (US$900/MT) and July (US$1220/MT), the monetary loss reached US$2.6 and US$3.5 million, respectively (1993 values). These figures indicate that efforts devoted to increasing total production may be in vain if more effective postharvest loss prevention strategies are not implemented.

The national economic effect caused by storage insects alone also can be significant. Insect losses (1.4%) nationwide were estimated at 745 metric tons by extrapolating losses measured during this study. Employing the market value for the months of May (US$900/MT) and July (US$1220/MT) 1993, the economic value of insect loss reached about US$670,500 and US$908,900 per year, respectively.

As noted by Haskell (1977), any development project that is concerned with subsistence farming and the organization of an integrated pest control program for small-scale farmers, should provide a plant protection package which includes practical and effective postharvest elements as part of the primary objective.

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