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GENETIC IMPROVEMENT AND COCOA YIELDS IN GHANA

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SUMMARY

This paper documents the yield gains attributable to the breeding and distribution of new cocoa varieties in Ghana, using data from a 2002 survey of 192 fields in the country's key cocoa producing regions. We find that planting the more recently-released varieties is associated with at least 42 % higher yields, and that genetic improvement accounts for much but not all of the observed correlation between tree age and cocoa yield. Fertilizer use is also very important, being associated with 19 % higher cocoa yield per 50 kg bag of fertilizer. We find no evidence that varieties differ in their response to fertilizer, pesticide use or labour, and no evidence of a decline in the yield advantage of new varieties over the 17-year age span observed in the sample.

INTRODUCTION

Crop breeding has led to substantial productivity increases and poverty alleviation around the world (Evenson and Gollin, 2003), and numerous case studies show similar effects in Africa (Masters *et al.*, 1998). These gains have been documented most often for annual crops; tree crop improvement is a much slower process, and its impact is spread over many decades as the trees develop, making it more difficult to observe.

Cocoa is among the world's most important tree crops, with a particularly long and significant history in Ghana. Introduced in the late nineteenth century, the crop spread rapidly across the country. By 1910, Ghana was the world's leading cocoa producer, accounting for 30–40 % of the global market (Bateman, 1990). Production levels continued to grow until 1964, then declined for twenty years. In 1984, a series of economic reforms, including regularly increasing farm gate prices, spurred recovery and have now reversed almost all of the previous decline (Food and Agriculture Organization, 2002; revised estimates are available from ED&F Man, 2004).

Genetic improvement may have played a key role in cocoa productivity, if only by influencing the crop's disease resistance and maturation rate. Indeed, for much of cocoa's history, new planting materials were the *only* science-based input available to farmers, who had few other means beyond their own labour with which to control disease or raise yields (Beckett, 1945). Over time, chemical pesticides and inorganic fertilizers became more important; in particular, it was long recognized that tree growth would eventually exhaust soil nutrient reserves (Charter, 1953), and soil nutrient availability is often already limiting to cocoa yields (Appiah *et al.*, 1997a). For a given

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Table 1. Stages in cocoa varietal development programme in Ghana.

Variety no.	Variety Name	Parent	Source	Extension period	Years to bearing†
	'Traditional' varieties				
1	Amelonado	Amelonado	Equatorial Guinea	Before 1887	6–8
2	Trinitario	Trinitario	Trinidad, Jamaica, and Venezuela	1900–1909	6–8
3	Mixed Amazon	Mixed Amazon	Peru via Trinidad	1950s	5–6
4	Originally Series II Hybrids	Upper Amazon × Amelonado and Local Trinitario	Peru and WACRI	1966–1970	4–6
5	Modified Series II Hybrids	Upper Amazon × Amelonado Hybrids	WACRI	1971–1985	2–3
	'New' varieties				
6	BRT collection	Inter-Amazon	British Research Team	Mid-1980s	2–3
7	Mutant hybrids (MV5)	Irradiation techniques	Current CRIG collections	1990s	4

Source: Author interviews with CRIG staff 2002; personal discussion with Rob Lockwood (2003) and review of literature.
† Years to bearing is sensitive to soil fertility and husbandry practices, especially shade management.

set of agro-economic circumstances, however, variety characteristics can have a large impact on what farmers can do.

The recovery of Ghana's cocoa industry from 1984 is typically attributed to a set of dramatic economic reforms, such as exchange rate devaluation that raised the profitability of using land and labour for the production of all agricultural products as well as increasing farm gate prices. But it also involved sector-specific efforts to revive the cocoa industry, including particularly the multiplication and distribution of new varieties (Abdulai and Reider, 1996). This paper outlines the development and impact of these varieties, recognizing that the economic reforms and other factors helped make their adoption profitable, and that the contribution of genetic improvement to productivity can be seen only in the context of other efforts with respect to pest control, soil fertility and crop management.

MATERIALS AND METHODS

Cocoa varieties in Ghana

The origin of the cocoa planting material available in Ghana is summarized in Table 1. In 1878, a trader named Tetteh Quarshie returned home from Fernando Póo (now Bioko in Equatorial Guinea) bringing with him cocoa seeds of the highly uniform West African Amelonado variety (variety 1 in Table 1). These were planted in the Akwapim mountains of the Eastern Region of the Gold Coast (now Ghana). Nearly a decade later, Governor Griffiths, then Governor of Ghana, effectively repeated Tetteh Quarshie's introductions (Lockwood and Gyamfi, 1979), planting the trees in the Botanic Gardens at Aburi. There were further introductions to Aburi between 1900 and 1909 of Trinitarios from Jamaica, Trinidad and Venezuela (variety 2 in Table 1).

The seedling varieties that are planted today originate in cross-breeding efforts that began in 1938, with the establishment of the Central Cocoa Research Station, later the West African Cocoa Research Institute (WACRI) and now the Cocoa Research Institute of Ghana (CRIG). At that time, it was estimated that over 90 % of the trees in Ghana were of Amelonado type, the remainder being descendants of the Trinitario introductions.

When launching the research programme, a collection of clones was made from experimental farms and farmers' cocoa, since it had been agreed that planting material should be distributed as seed and not as clones (Posnette, 1943). Using the seedling progeny of 28 West African Amelonado clones and two clones of doubtful antecedents, the first progeny trials of high yielding cocoa selections were planted between 1940 and 1943 (Posnette, 1951). Two non-Amelonado progenies, E1 and N38, gave the highest number of bearing trees, the most pods and the highest weight of beans per pod. The second progeny trial, which took place up to 1950, was designed to compare the yield of the progenies of one Amelonado and 35 Trinitario clones. The results confirmed the early bearing habit and relatively high yield of the E1 progeny in the first trial, and indicated that certain Trinitario clones, notably TF1, may have even higher yielding progeny. Detailed results of these and subsequent trials can be found in Posnette (1951), Knight and Rogers (1955), Glendinning and Edwards (1962), Glendinning (1963) and Lockwood (1976).

It became apparent that the locally available germplasm would not permit a successful breeding programme for resistance to mirids (*Distantiella theobromae* and *Sahlbergella singularis*) and/or Cocoa Swollen Shoot Virus Disease (CSSVD) (Posnette, 1951). In 1944, a solution to this problem was sought in the transfer of seedling germplasm from Trinidad, including material that had originated from Brazil, Costa Rica, Ecuador, Nicaragua, Peru, Surinam, Trinidad and Venezuela.

The Upper Amazon collections from Peru showed superior vigour and precocity when compared with the Lower Amazon, Criollo, Ecuador, Trinitario and West African Amelonado types (Posnette, 1951). Ghana's need to replace trees that had been cut out in the campaign to contain the spread of CSSVD prompted the rapid multiplication of the Upper Amazon material. Its precocity was seen to be especially advantageous (Knight and Rogers, 1955) in enabling affected farmers to get back into production quickly. Plots of mixed second generation open-pollinated Upper Amazon material were established from 1950 onwards, to test the material under farmers' management.

In 1954, 10 of the Upper Amazon types were approved for distribution to farmers as third generation open-pollinated seed (Hammond, 1955). An eleventh type was added in 1957 (Hammond, 1958). This became known as the 'F_3 Amazon' or 'Mixed Amazon' material (variety 3 in Table 1). By March 1961, sufficient pods and seeds had been distributed to plant an estimated 60 000 ha (Glendinning and Edwards, 1962).

While the Mixed Amazons were being multiplied, Knight and Rogers made exploratory crosses between Upper Amazon seedlings selected within the Trinidad introduction and some of Posnette's (1943) local Trinitario selections or their self-pollinated descendants. Trials of seven and six potential new varieties (including reciprocal crosses) were established in 1952 and 1954 respectively. They became known as the 'Series II Hybrids' (variety 4 in Table 1). Strictly speaking, these and other cocoa varieties are bi-parental crosses rather than hybrids, since the parents are not inbred, but the term hybrid remains widely used to describe them. In 1955, seven of these varieties were selected for evaluation at more sites, with a single inter-Upper Amazon cross included at all of them. In 1960, bi-clonal seed gardens were established to mass produce seeds of six Series II Hybrids, relying on self-incompatibility and natural pollination. There were five Upper Amazon, three Amelonado and three Trinitario parents.

The accumulated results from all the Series II trials were re-assessed in 1970. It was concluded that as a group, the Upper Amazon × Amelonado hybrids, known as the 'Modified Series II Hybrids' (variety 5 in Table 1), were preferable to the Trinitario hybrids, yielding about 11 % more and showing markedly lower losses from black pod disease. (It is noteworthy here that the Series II trials were assessed for their resistance to black pod when it was caused by infection with *Phytophthora palmivora*; the later arrival of a more virulent species, *P. megakarya*, is well documented by Opoku *et al*. 2000.) In trials, the best Amelonado hybrid yielded 15 % more than the average of the Trinitario hybrids, with lower losses from black pod disease. This difference was expected to be amplified under smallholder management. The one inter-Amazon hybrid was comparable to the Amelonado hybrids in field performance (Anon, 1970). In a single comparison, the Amelonado hybrid out-yielded the Amelonado by about 45 %, compared to 14 % for the Trinitario hybrids (Lockwood, 1976). In Ghana, there was no formal comparison between the Series II Hybrids and Mixed Amazons (variety 3, Table 1).

In 1969, seed garden output was low, because the Upper Amazon clones had proved to be easier to establish, more vigorous and more floriferous than the Amelonados and Trinitarios. A manual pollination technique was developed that allowed large scale production of high quality seed from the Upper Amazon parents, at low cost, and with a measure of control over seasonal periodicity of production (Edwards, 1973). This allowed substitution of Amelonado for the local Trinitario in all the seed gardens planted with one of the four self-incompatible Upper Amazon clones (the fifth was self-compatible and was abandoned). Seed production averaged 1.65 million pods per annum from 1973/74 to 1991/92, with a range of 1.16 to 2.05 million (E.G. Asante, personal communication, 2003). From 1992 to 2001, the average was 1.5 million, with a total of 1.99 million in 1997 and 3.0 million in 2001. Assuming 125 pods are required to plant one hectare of cocoa (allowing considerable wastage), 1.5 million pods is enough for planting 12 000 ha per annum.

When the change was made to using Amelonado as the pollen parent, it was known that some Upper Amazon clones confer on their progeny a useful measure of resistance to CSSVD (Posnette and Todd, 1951; Legg and Kenten, 1971). Trials were planted to evaluate Upper Amazon clones as alternative pollen parents for the four self-incompatible Upper Amazon parents (Lockwood, 1981). The objective was to combine the ease of establishment and precocity of the Series II Hybrids with greater resistance to the spread of CSSVD. In 1985, the results of these trials were used to choose four Upper Amazon pollen parents for each of the seed gardens. On average, these crosses were slightly higher yielding and showed lower black pod losses than the Amelonado crosses they replaced (Enuson and Adomako Boamah, 1985). These crosses are referred to here as the ‘BRT Hybrids’ (variety 6 in Table 1), because they were established by a British Research Team working at CRIG at that time. A recent evaluation of 23 farm plantings with this type of material showed that virus spread had been relatively slow over a 25-year period (Ollennu and Owusu, 2002), confirming the results of Legg and Lockwood’s (1981) field experiments.

Several of the Series II Hybrids and the later BRT Hybrids were planted in large scale agronomy experiments. The results from those trials indicated that breeders’ trials tended to under-estimate the difference between bi-parental crosses. In one experiment, the best of the Series II Amelonado crosses outyielded a Series II Trinitario cross by 53 % based on the number of useable pods (Ampofo *et al.*, 1986). The difference in yield of dry beans would have been smaller given that the Amelonado cross has smaller pods. In another trial, three of the BRT hybrids had potential yields 28 % higher than a Series II Amelonado cross (Appiah *et al.*, 2001). Enuson and Adomako Boamah’s (1985) black pod data suggest the difference in actual yields would have been larger than this. In a third trial, three of the BRT hybrids outyielded the best of the Series II Amelonado crosses by 36 % (Osei-Bonsu *et al.*, 2002).

The survey

The purpose of our study was to assess the impact of new varieties on farmers’ fields, controlling for other factors. Following local usage, we group all of the pre-1980 varieties as ‘traditional’, and refer to all later releases as ‘new’. The discontinuity around 1980 arises in part because, through the late 1960s and 1970s, a variety of government policies limited the profitability of cocoa production, leading farmers to neglect standing trees and not to plant new ones. Then, in early 1980, Ghana experienced a devastating bushfire and drought in the south, and also continued infestation by CSSVD in the east that led to a restart of government-enforced cutting of cocoa trees, particularly the older ones (Anon., 1995). Finally, the 1984 economic reforms sharply raised the profitability of new plantings, and at the same time the government’s Cocoa Rehabilitation Project (CRP) funded the large-scale distribution of the most recently-released cocoa varieties to farmers (Bloomfield and Lass, 1992). Some farmers continued to replant their old varieties, however, which allows us to distinguish the contribution of post-1980 genetic improvement from the many other determinants of cocoa yield.

Information for this paper comes from both primary and secondary sources. The primary source is a field survey undertaken in mid-2002 in the Ashanti and Western Regions, Ghana’s principal cocoa growing areas. A total of 123 farmers from 20 villages were sampled and interviewed by this paper's first author, accompanied by a local translator. The number of fields owned by each farmer varied between one and three resulting in a total of 192 fields being analyzed in this study. Secondary data on the breeding programme of cocoa in Ghana were obtained through research reports, journal articles and personal communication with individuals involved in the cocoa sector and its genetic improvement.

In our sample of farmers, 73 % owned one field, 19 % owned two and 8 % owned three fields. The survey asked the farmers to describe the types of cocoa being grown, sources of seedlings, their dates of planting, number of cocoa trees in their field(s) and the size of their field(s) and also asked about a range of other factors that might influence cocoa yields. Some data were also collected on the other crops being grown.

Multistage random sampling was used to select the districts, villages and farmers. Randomization was done by dipping into a bag and picking out names written on pieces of paper, each in turn without replacement, first for the districts and then for the villages. The number of districts and villages selected in each region was made proportional to the number of cocoa-buying societies or produce-buying centres, to reflect the number of cocoa-producing villages. Two districts and eight villages were selected from the Ashanti region, two districts and eight villages from the Western North region, and one district and four villages from Western South.

For farmer selection, the research team made visits to each selected village where meetings were held with the cocoa-buying clerks, during which a list of the cocoa farmers was prepared from the records of the buying clerks. From this list, a dip was drawn from a bag to select farmers for the survey. Noting the time it took to fill a questionnaire and make a field visit during the pre-testing phase of the survey, the research team decided to interview six to eight farmers per village, depending on village size.

Before commencing interviews, the Chief of each village was visited to explain the team's mission and how farmer selection was to be done; then the same explanation was given to a gathering of farmers, at which time the dip was drawn. The selected farmers were invited to the buying centres of their respective buying clerks to begin filling in the questionnaire; in most situations, farmers came with some household members and/or friends, who greatly helped in correcting or reminding them of some facts in response to the questions. Extension personnel and buying agents were also often present, and typically a field visit was made before the questionnaire was completed.

Our sample consists of randomly selected farmers irrespective of social, economic or financial status or gender, but it is important to note that it includes only farm owners, in the sense of the individuals who were recognized by the cocoa-buying clerks as their customers. Our survey villages actually have many fields that are managed on a share basis: typically the caretaker receives one-third of bean sales, referred to as *abusa*, but in some cases the caretaker is paid a 50 % share, referred to as *abunu*. Caretakers who were not themselves the sellers of cocoa were included in the pre-testing of the questionnaire, but their information about tree variety, input use and output sales appeared to be less reliable than the responses of tree owners. To limit the influence of such uncertainty on our results, we chose to sample only field owners who could be found in the local area. Our sample therefore excludes any fields owned by absentee owners, which makes the results not fully representative of all farm management systems. It remains possible that fields with absentee owners benefit less (or more) from genetic improvement than fields with local owners.

Farmers easily recalled each field's planting dates. Field sizes were generally well known due to the practice of hiring workers in proportion to field size, and for new varieties the field sizes were confirmed by recall of the quantity of seedlings bought from the seed centres. Output levels were taken from total beans sold as recorded in the farmer's book; farmers with two or more fields were asked to report production per field separately, and their sum was cross-checked against total sales in the farmer's record book.

To identify the varieties planted in each field, farmers' recall was cross-checked by the lead author, based on criteria provided by CRIG researchers. Experienced extension agents and cocoa-buying clerks accompanying the lead researcher also made separate identifications, to ensure accuracy. Typically, whole fields had been planted to new stock simultaneously, with a single variety. The boundaries between fields are not always self-evident, but farmers were swift to identify them. In a few cases, particularly the oldest fields, farmers noted that they had planted traditional varieties from their own collection gradually over as many as three consecutive seasons, so for these fields our method introduces some error in the exact age of each tree.

Where disparities occurred, special care was taken to reach agreement between the farmer and the buying clerks, family members and friends who were typically present during the interview. Buying clerks in particular were important in validating the figures, affirming that they made several visits to the fields of their customers through out the farming season in order to secure beans. Some buying clerks who engaged in forward contracting had particularly vivid knowledge of their customer's fields.

Where there was any evidence of uncertainty over field sizes, a direct measurement was taken, by marking out at least three quadrants per field and counting the number of trees per quadrant. This count was then related to the area of the field to obtain total cocoa stand after measuring the field and the area computed. Farmers were able to delineate boundaries between two or more fields that looked continuous from the outside, based on planting dates.

Description of the data and analysis

Descriptive statistics of the data collected are presented in Table 2. In addition to the average area of 3.5 ha with cocoa listed in Table 2, farm households planted a mixture of food crops (cassava, plantain, yam and maize) for home consumption, on an average land area of 0.8 ha. The input use levels reported in the table are far below agronomic recommendations, which is typical for low-income farmers who have little savings or credit available to them at the start of the growing season.

Table 2. Descriptive statistics for key variables ($n = 192$).

Variable		Mean	Standard deviation	Min	Max
Output	kg ha^{-1}	294.8	122.69	71.2	754.6
Output (Traditional)	kg ha^{-1}	258.8	82.69	101.0	552.0
Output (hybrid)	kg ha^{-1}	497.0	107.84	328.7	933.6
Field area	ha	3.5	3.13	0.4	17.0
Age of plantings	years	20.1	12.79	3.0	56.0
Fertilizer use	50 kg bags ha^{-1}	0.5	1.25	0.0	6.5
Pesticide use	l ha^{-1}†	1.9	2.88	0.0	22.0
Hired labour use	man days ha^{-1}	10.9	6.82	0.0	125.7
Family labour use	man days ha^{-1}	23.4	7.50	1.9	170.2
Family size	persons	10.7	4.85	1.0	25.0
Dependents	persons‡	5.1	2.63	0.0	11.0
Age of farmers	years	46.3	15.47	20.0	77.0
Credit	1= has access, 0 otherwise	0.5	0.50	0.0	1.0
Education of farmer	1= literate, 0 otherwise	0.5	0.50	0.0	1.0

Source: Authors' survey data, 2002.

† The pesticide used by surveyed farmers used to be gammalin, a trade name for lindane, but this is no longeravailable or used in Ghana.

‡ Defined as those dependent on farmer for livelihood, without contributing to the farm.

The purpose of our survey was to test the correlation between variety choice and cocoa yield, controlling for other factors as expressed in equation (1):

$$ln(yield_i) = \alpha + \beta h_i + \boldsymbol{\mu x_i} + \varepsilon_i \qquad (1)$$

where $ln(yield_i)$ is the natural logarithm of the yield of cocoa per hectare from the ith field, h_i is a (0,1) variable equal to one if a new 'hybrid' variety was planted there, $\boldsymbol{x_i}$ denotes a vector of additional observed control variables as described below, α, β and $\boldsymbol{\mu}$ are unknown parameters, and ε_i is the error term.

The semi-log functional form of equation (1) was chosen empirically, based on a goodness of fit test by which it provided the highest r^2 among four functional forms: linear, semi log, square root and quadratic. Using the natural logarithm of yield limits the influence of outlier observations, and offers an intuitive interpretation of the estimated coefficients in terms of the percentage change in yield associated with a one-unit change in each variable.

The coefficient of greatest interest is β the percent change in yields from using new varieties. Our estimate depends heavily on controlling for other factors that might influence yields. Several such factors were observed in the survey and included in x_i, notably the quantities of fertilizer, pesticides and hired labour, as well as the age of the tree and possible interaction effects between these variables. Omitted variables could also matter, such as soil quality and local disease pressure. In particular, since the new varieties were not randomly assigned to each field but were chosen by farmers in pursuit of higher yields, we are particularly concerned with what economists call endogeneity bias: if farmers planted new varieties on fields that were particularly well-suited to them, then an ordinary least squares (OLS) estimate of β would be biased upwards, overstating the yield increase that might be obtained from planting new varieties on other fields.

To control for endogeneity bias, the standard remedy is to find variables that might influence variety choice without influencing yield, and use them as 'instrumental variables' in a two stage least squares (2SLS) regression. In this study, the instruments we use are the farmer's education and access to credit: these turn out to be correlated to the use of new varieties, presumably because education and credit gave farmers easier access to the planting material. That difference provides an unbiased test of the influence of a new variety, to the extent that education and credit have no other influence on yields once we have controlled for observable inputs using $\boldsymbol{x}_i$.

The 2SLS test begins with a first stage equation describing the farmer's decision to use new varieties:

$$h_i = \delta_0 + \boldsymbol{\delta_1 x_i} + \boldsymbol{\Phi z_i} + e_i \tag{2}$$

where $\boldsymbol{\delta}$ and $\boldsymbol{\Phi}$ are matrices of unknown parameters, $\boldsymbol{x_i}$ are the variables that influence yield and might also influence new variety adoption, $\boldsymbol{z_i}$ are the instruments (education and credit), and e_i is the error term. The dependent variable is dichotomous, so the equation is estimated using a probit regression. Our purpose is to obtain a set of predicted values for h_i, denoted $\hat{h}_i$, representing hybrid adoption due to observed factors including some farmers' greater access to planting materials, purged of any omitted variables such as soil quality or local disease pressure that might influence the payoff to new varieties.

The 2SLS approach uses $\hat{h}_i$ in place of h_i in equation (1), so that its estimated coefficient β is no longer subject to endogeneity bias. In effect, β now represents the percentage change in yields associated with a quasi-experimental, exogenous increase in farmers' access to new varieties.

RESULTS AND DISCUSSION

The results for our estimated yield function are shown in Table 3. The first model (a) specification shows direct influences only, and the second (b) tests for interaction and non-linear effects of tree age.

Results show clearly that adoption of a new variety is closely correlated with yield, increasing yield by at least 42 %. Cocoa yield also increases with fertilizer use, at an estimated rate of 19 % per 50 kg bag which is consistent with the findings of Appiah *et al.* (1997b). Interaction effects between new varieties and input use were not significant: in this sample at least, the productivity gain from new varieties did not depend on using fertilizer, pesticides or additional labour.

An important aspect of the results from Table 3 is that cocoa yields do decline with age, particularly at high levels of age, but this pure senescence effect is much smaller than the effects of variety and fertilizer use. Younger trees do tend to have higher yields, but mainly because they are more likely to have new genetics – age alone is much less important once we control for variety.

Table 3. Yield function coefficients estimated using two stage least squares probit.

Dependent variable: *ln (yield)*	Model (a): preferred specification Estimated coefficient	 *s.e.*	Model (b): nonlinear age Estimated coefficient	 *s.e.*
	$n = 192$ for each model			
Independent variables				
Intercept	4.81	0.053	4.46	0.080
New variety adoption	0.42*	0.045	0.59*	0.055
Fertilizer use	0.19*	0.035	0.19	0.156
Pesticide use	−0.00	0.014	0.07	0.037
Hired labour use	−0.00	0.002	−0.00	0.002
Age of planting	−0.01*	0.002	0.01	0.006
Age of planting-squared			−0.00*	0.000
Interaction effects				
New variety × fertilizer			−0.08	0.164
New variety × pesticide			−0.07	0.040
New variety × labour			−0.00	0.004
Fertilizer × pesticide			0.31	0.253
New variety × fertilizer × pesticide			−0.23	0.264
r^2	0.695		0.750	

* $p < 0.001$.

r^2 = amount of total variation in the dependent variable that is explained by the independent variables.

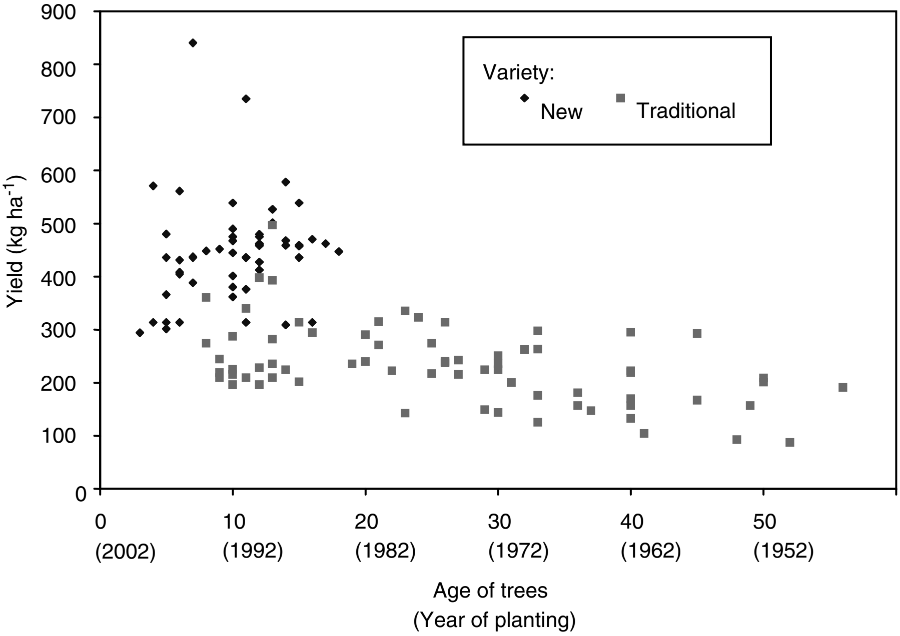

Figure 1. The effect of tree age on yields with new and traditional varieties.

The degree to which varietal improvement helps explain the vigour of younger trees can be visualized clearly in Figure 1, which shows yield by age of planting. Looking at Figure 1 without distinguishing between the old and new varieties suggests that tree yields peak at about age 13 years, and decline thereafter. With more careful examination, however, it is clear that younger trees have higher yields mainly because they are more likely to be of a new variety. The old varieties peak later and decline more slowly, while the new varieties have not been around long enough to show any senescence at all.

The new varieties first appear in our sample on a field that was planted in 1985, and so was 17 years of age at the time of the survey. That field now yields approximately twice as much cocoa per ha as the similar-aged fields that were planted with traditional varieties. This yield advantage holds for subsequent plantings as well. After 1985, our sample is increasingly dominated by the new varieties, and the traditional varieties disappear entirely from the fields planted after 1995. Although yields vary over the lifespan of the tree, rising as it matures, then stabilizing and eventually falling, there is no evidence that the new varieties are more vulnerable to yield decline over the 17-year horizon for which we have data.

CONCLUSION

This study is believed to be the first field verification of the yields of improved cocoa varieties when planted by farmers in Ghana. The gain in yield is even larger than would have been predicted from the results of the breeders' trials, but is consistent with the results of larger scale agronomy trials.

We find that the multiplication and distribution of new cocoa varieties developed in Ghana has raised farmers' yields by at least 42 %, controlling for other factors. That yield difference is attributable to almost 50 years of breeding effort, followed by large-scale multiplication and distribution of new planting materials to farmers. The economic policy reforms of 1984 were critical to raising both private and public investment in cocoa production. Without the new varieties, however, yields would have been much lower – offering a much smaller payoff to policy reforms and lower incomes for farm families.

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