Cocoa introductions into Ghana

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ABSTRACT

Cocoa breeding and selection programmes in Ghana and other West African countries have been based largely on existing cultivated populations or on few collections of wild cocoa. The most widely used cocoa germplasm derives from the material collected by F. J. Pound during the periods 1937-1938 and 1942-1943 and distributed as the Iquitos Mixed Calabacillos (IMC), Nanay, Parinari, Scavina, and the Pound series of clones. This material collected in the Upper Amazon region has been particularly successful, suggesting that cacao would be greatly improved if more germplasm material were provided for use by breeders. Maintaining adequate genetic variability in cocoa germplasm collection, essential for sustainable cocoa production, can be realised through active and conscious germplasm acquisition. Because there is the risk of accidentally introducing diseases and pests along with cocoa germplasm material, effective indexing procedures, together with the availability of final quarantine houses in individual producing countries, are essential to ensure that introduced materials are free of diseases and pests. To be successful as breeding material for producing improved varieties for farmers, the introductions must have some desirable characteristics acceptable to chocolate manufacturers and farmers.

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RÉSUMÉ

ABDUL-KARIMU, A., ADOMAKO, B. & ADU-AMPOMAH, Y.: *Les introductions de cacao au Ghana.* Les programmes de reproduction et de sélection de cacao au Ghana et dans d'autres pays de l'Afrique occidentale ont été fondé en grande partie sur les populations de cultures existantes oú sur un tous petit nombre de collections de cacao sauvage. Le germeplasme de cacao le plus utilisé sur une grande étendue vient de matières ramassées par F. J. Pound en 1937-1938 et en 1942-1943 et distribuées sous les noms d'Iquitos Mixed Calabacillos (IMC), Nanay, Parinari, Scavina et Pound comme des séries de clones. Une succès particulier a été réalisé avec cette matière ramassée de la région de Haute Amazone. Ce succès suggère que même de plus grandes améliorations en cacao pourraient être possible si beaucoup auraient été disponible pour utilisation par les phytogéticiens. Le maintien de variabilité génétique adéquate en collection de germeplasme de cacao est essentiel pour la production durable de cacao et ceci pourrait être réalisé par acquisition active et consciente de germeplasme. Puisqu'il y a le risque d'introduire par hasard les maladies et les insectes nuisibles avec la matière de germeplasme du cacao, les procédures efficaces d'indexation, ainsi que la disponibilité de salles de quarantaine finale dans chaque pay producteur sont essentiel pour assurer que les matietes introduietes sont sans maladies et insectes nuisibles. Pour réussir comme matière de reproduction pour la production de variétés améliorés pour les agriculteurs, les introductions devraient avoir quelques caractéristiques désirables er acceptables aux fabriquants de chocolat et aux agriculteurs.

Introduction

Cocoa (*Theobroma cacao* L.) is indigenous to the wet tropical forest of Central and Southern America from Mexico to Bolivia and Brazil, and has been introduced throughout the tropics in the past 400 years (Allen & Lass, 1983). Over 7300 different genotypes of cacao are recorded worldwide, the largest collections being held in Trinidad, Brazil, Costa Rica, Equador, Ghana, Cote d'Ivoire, and Malaysia (Paulin & Eskes, 1995). Over 700 genotypes have been assembled at the Cocoa Research Institute of Ghana (CRIG), Tafo. Collecting, conserving, and using cocoa genetic resources have become important components of international programmes for improving cocoa aimed at bringing about sustainable cocoa production.

Breeding and selection for improved cocoa varieties depend on availability of desired genetic variability in the base germplasm population. Most breeding and selection programmes have been based on existing cultivated populations or on few collections of wild cocoa. Cultivated populations, particularly in Africa, are descended from a few original introductions and are, therefore, genetically fairly uniform (Allen, 1982). The scope for improvement within such populations is, thus, limited without introducing new germplasm.

Germplasm exchanged internationally involves a risk of accidentally introducing, along with the host plant material, pests and diseases such as witches' broom and wilt caused by *Crinipellis perniciosa* and *Ceratocystis fimbriata*, respectively, from South America; and pod borer from South-east Asia. Effective indexing procedures are, therefore, required to ensure that introduced material is free from pests and diseases.

This paper presents cocoa germplasm collection activities at CRIG, Tafo-Akim.

Early introductions of Amelonado and local Trinitario cacao

Almost all the cocoa in Ghana before 1943 originated from few seeds introduced from Fernando Po in 1879 by Tetteh Quarshie, but Posnette & Todd (1951) believed that this is not strictly true, because much seed was distributed from the Aburi cocoa that was introduced from Sao Tome in about 1890 by Governor Griffiths (Legg, 1972). However, the bulk of the cocoa in Ghana before independence descended from these early introductions. In the early 1940s, about 95 per cent of the cocoa trees in Ghana comprised the 'introduced' Lower Amazon Forastero variety, now known as West African Amelonado. The remainder were descendants of other early introductions called 'local Trinitarios' (Anon., 1963; Glendinning, 1964; Lockwood, 1976). During the period 1857-1868, the Basle Mission introduced some cocoa into the country (Legg, 1972), but these introductions did not make any significant impact on cocoa cultivation in the country.

The West African Amelonado derived from introductions made between 1879 and 1892 from islands in the Gulf of Guinea. They were introduced to these islands previously from Brazil by the Portuguese. The Amelonado being used in Ghana now is derived from the introductions made in the late 1880s and early 1890s to the Aburi Botanical Gardens by Governor Griffiths (Legg, 1972), and selected either from the Asuansi plot which was planted from the Aburi collection, or from plantings on the old German station at Kpeve.

The 'local-Trinitario hybrids' are non-Amelonado cocoa collected by Posnette in Ghana in the late 1930s and early 1940s. These seem to be all derived from four small introductions of other types of cocoa – 'Pentagona', 'Ocumare', 'Cundeamor' and 'Criollo' – made to the Aburi Botanical Gardens in 1901, 1905, 1906 and 1909, respectively, by Governor Griffiths (Lockwood & Gyamfi, 1979). Some material planted at Aburi was also distributed to other stations of the Divisions of Agriculture, and to farmers. Collections were made from Aburi, other stations, and farmers' farms. Because interbreeding between the various cocoa types had probably taken place and also between these types and Amelonado, the general term 'local-Trinitario hybrid' was used to describe segregating materials arising from natural hybridization to avoid commitment to the precise status of any individual selection made.

Posnette's introductions from Trinidad

Soon after cocoa breeding began in Ghana in the mid-1930s, it became clear that the limited locally available germplasm would not permit a successful breeding programme because there was very little genetic variation in the material in vegetative characteristics and reaction to prevailing diseases and pests such as *Phytophthora* black pod disease, cocoa swollen shoot virus disease (CSSVD), and capsid pests. Pound (1938), during his expedition to the upper reaches of the Amazon, made a collection of *Theobroma cacao* L types which would hopefully be resistant to witches' broom disease. These were sent to Trinidad as material for his breeding programme. Posnette (1943) visited Trinidad from Ghana and collected pods from these trees because he was interested in their possible resistance to CSSVD (Knight & Rogers, 1955; Legg & Kenten, 1968; Lockwood, 1976).

Both open- and hand-pollinated pods were dispatched by air to Ghana. Few pods from wild-type Lower Amazons, together with some Trinitario and Criollo types, were included in the *Theobroma cacao* introductions from Trinidad. Each pod was designated by a serial number with the prefix ‘T’ for Trinidad; numbers below T60 were open-pollinated whilst those from T60 were hand-pollinated. After a period of quarantine in Accra, the resulting seedlings were planted at Tafo in 1945 (Rogers, 1955). Seven other *Theobroma* species and two *Herrania* species were also included in the introductions.

Pound’s Upper Amazon introductions

Between 1945 and 1972, several consignments of cocoa germplasm material were introduced to Ghana by the British Research Team to broaden the genetic base of the breeding material available to the team for use (Table 1). The material, which was originally collected by F. J. Pound during the periods 1937-1938 and 1942-1943 in the Upper Amazon basin in South America, comprised largely four populations – Nanay (NA), Parinari (PA), Iquitos Mixed Calabacillo (IMC), and Scavina (SCA).

TABLE 1

Cocoa Germplasm Material Received at CRIG, Tafo, 1944-1972

Clone	*Origin*	*Date received*
*‘T’ clones (T1 to T102)	Trinidad	1944
NA 32, PA 35	**RBG – Kew	1952
NA 31, 33, IMC 60, 76, PA 7	RBG – Kew	1956-1957
23P, UF 29, EET 94, UF 650, 22P, POUND 12, GA 11, UF 221, 10R, GS 36, 9R, GS 50, EET 390, GS 7, SIC 1, PA 121, UF 12, 117R, GS 29	Miami	1965
SCA 12, 9, 6, IMC 47, 26, 60, NA 31, 32, 33	Nigeria	1968
UF 654, 668, 672, 242, 2R, IMC 67, GS 29, EET 94	Miami	1968
G 8, DR 1, 38, GW, SNK 109, SL 6, SM 2, PA 150 POUND 7, WA 40, 48, 57, ICS 39, 89, 100, S 52	Wageningen	1970
SIAL 8, 407, SIC 3, ICS 84	Miami	1971-1972
NA 2, 27, 58, 68, 70, 121, 154, 164, 170, 186, 204, 224, 225, 227, 235, 242, 244, 273, 280, 335, 344, 381, 427, 484, 521, 535, 681, 682, 691, 702, 707, 710, 724, 725, 729, 739, 744, 749, 750, 752, 757, 758, 770, 780, 785, 794, 802, 847, 876, 884	RBG – Kew	1971-1972

*The parentage of the ‘T’ clones is given by Lockwood & Gyamfi (1979)
**RBG: Royal Botanic Gardens

Later introductions

The range of cocoa germplasm resources at CRIG was further increased later by introducing large consignments of clones, originating from the Caribbean, Central and Southern America (Legg, 1981). Some clones in the later introductions (Tables 2 and 3) are not closely related to the NA, PA, IMC, and SCA material received earlier. New introductions are being acquired continually to broaden the genetic base of the cocoa germplasm at CRIG. The new introductions are different from the earlier ones in pod and bean characteristics such as bean weight, number of beans per pod, percentage shell content, and fat content of dried beans (Adomako & Adu-Ampomah, 2003). Details of the history of cocoa introductions to Ghana up to 1968 are provided by Lockwood & Gyamfi (1979). Later introductions are reported in successive Annual Reports of CRIG.

Vegetative characteristics and yield of the introductions

Progenies of Upper Amazon cocoa are characterized by exceptional vigour, early-bearing, and high yields (Thresh *et al*., 1988). The traditional West African Amelonado variety, locally referred to as "Tetteh Quarshie", starts to bear fruits about 5 years after field planting and reaches maximum yield of 500 to 1,000 kg ha^{-1} under favourable field management. Upper

TABLE 2

Cocoa Germplasm Material Received at CRIG, Tafo, 1972-1975

Clone	*Origin*	*Date received*
IMC 78, PA 269, NA 443, 691, 725, 904, 929, CC 10, 10P	RBG – Kew	1972-1973
MA 12, RB 29, 39, 42, 46, 49, BE 8, C-SUL 7, APA 4, 5, SPA 5, 7, 9, 10, SC 5, 6, SIAL 93, EET 48, 333, 399, SGU 60, 71, 89, PA 16, 81, 169, POUND 11	Miami	1972-1973
CC 10, EET 377, PA 56, 70, 211, IMC 44, 83, ICS 95, SCA 12	RBG – Kew	1972-1973
CC 40, 56, 57, EET 12, 80, 134, 156, ICS 29, 47, 98, 100, SC 24, 49, 51, 55, SGU 3, 50, 89, SIAL 42, 44, UF 10, 11, 668	Miami	1974-1975
BE 3, Catongo, CAS 3, CC 10, 11, 38, EEG 25, 48, 64, 65, EET 353, 397, GC 29, ICS6, 95, IMC 3, 5, 6, 13, 14, 16, 22, 39, 44, 47, 49, 51, 54, 57, 61, 77, 78, 83, 105	RBG – Kew	1974-1975
LEPM-Pentagona, LEPM-Roja, LEPM-Amarilla, Laranje, M 180, Matina, Mocorongo, MOQ 210, 528, 647, NA 58, 242, 691, 727, 929, P 8, 10, RB 41, SCA 3, 5, 12, 23, SCR 4, SGU 69, SIAL 93, 98, 339, UF 11, 168, 221, 667, 705, 713	RBG – Kew	1974-1975
PA 18, 46, 51, 56, 65, 70, 88, 118, 134, 195, 211, 303, 310, Pound 1b, 4a, 5c, 7b, 8a, 11b, 13b, 16b, 21a, 25c, 31a	RBG – Kew	1974-1975

TABLE 3

Cocoa Germplasm Material Received at CRIG, Tafo, 1975-2004

Clone	*Origin*	*Date received*
AMAZ 5-2, 15-15, BE 10, EQX 3360-3, ICS 43, LCT-EEN 28/51, 37F, 37G, 37I, 46, 127, MAN 15-2, MO 20, MXC 67, PA 107, SCA 6, 24, SIAL 339, SPEC 54-1, UF 676	Reading University	1975-1990
NA 33, PUCALA 1, SC 1, 3, 9, 10, TJ1	RBG – Kew	1990-1991
ICS 84, SNK 16, 32, 64, 413	Montpellier	1995-1996
AMAZ 12-4, DOM 14, GDL 7, 11, GU 133C LCT-EEN 28/S1, MA 12, MAR 13, NA 756, PLAYA ALTA 2, PUCALA 1, SC 10, SCA 11, SPEC 160-9, 184-2	Reading University	1999
ABC 146, AM 243, Borne 7A6, C 15-61, C 40, DOM 4, 30, EET 58, 95, GS 6, KER 2-E, 6, 7, 9, LV 6, 28, PLAYA ALTA 2, R 39 (MEX), SJ 119, SPA 16	Reading University	2000
AMAZ 15, COCA 3370/5, EET 59, GU 175, 255/P, ICS 43, 75, LV 20, NA 33, PA 137	Reading University	2002
AM 1/8, 1/95, 2/43, APA 4, B 5/3, B 5/7, B 7/A-6, B7/B-5, CERRO AZUL 10, CL 19/10, CL 19/49, CLM 90, COCA 3380/1, 3348/52, CRU 70, 100, JA 1/9, 1/19, 3/20, 5/25, 6/2, 10/12, LCTEEN 62/S-4, 163/A, 241, 302, LP 1/41, 4/32, 5/19, LV 20, LX 6, 28, MAR 9, TSH 516, 774, *Herrania nitida*	Reading University	2004

Amazon cocoa progenies, under similar conditions, start bearing in the 3rd year after field planting and reach maximum yields of about 2,000 kg ha^{-1} (Toxopeus, 1964). Trees of Posnette's Trinidad introductions are also extremely vigorous. They come into bearing earlier and are higher yielding than Amelonado and the local Trinitarios (Posnette, 1951; Knight & Rogers, 1955). Some introductions from Trinidad (Table 4) were so promising for vigour, yield and resistance or tolerance of the CSSVD that progenies from 11 of them were approved for distribution to farmers in 1954 and 1958 for rehabilitating areas devastated by the CSSVD (Thresh *et al*., 1988). Trees of the 11 approved types all originated from one region in Peru in the areas of Rio Nanay (NA 31-34), Iquitos Island (IMC 47 and IMC 60), Parinari on the Rio Maranon (PA 7 and PA 35), and a nearby unidentified locality (SCA 12). Progenies of these materials have been planted extensively in Ghana and elsewhere (Thresh *et al*., 1988), and have formed the basis of cocoa improvement in many countries for better establishment capacity, vigour, precocity, and yield potential than the traditional varieties (Amelonado, Trinitario) (Kennedy *et al.*, 1987; Thresh *et al*., 1988; Glendinning, 1967; Paulin & Eskes, 1995; Adomako, Allen & Adu-Ampomah, 1999b).

The vegetative, yield, pod and bean

TABLE 4

More Promising Cocoa Introductions from Trinidad

Genotype	*Parentage*		
T12*	Scavina (SCA 12)	×	unknown male (pollen) parent
T16	Iquitos (IMC 24)	×	unknown male (pollen) parent
T17	Iquitos (IMC 53)	×	unknown male (pollen) parent
T60*	Parinari (PA 7)	×	Nanay (NA 32)
T63*	Parinari (PA 35)	×	Nanay (NA 32)
T65*	Parinari (PA 7)	×	Iquitos (IMC 47)
T72*	Nanay (NA 32)	×	Iquitos (IMC 60)
T73*	Nanay (NA 33)	×	Iquitos (IMC 60)
T76*	Parinari (PA 35)	×	Nanay (NA 31)
T79*	Nanay (NA 32)	×	Parinari (PA 7)
T81	Nanay (NA 320)	×	Nanay (NA 31)
T82*	Nanay (NA 32)	×	Parinari (PA 35)
T85*	Iquitos (IMC 60)	×	Nanay (NA 34)
T87*	Iquitos (IMC 60)	×	Nanay (NA 34)

* Progenies from these were formally approved for distribution to farmers

characteristics of the introductions that were made later (1975-1995) are similar to those observed in the Upper Amazon material (Adomako *et al*., 1999). Generally, the Parinaris (PA) are better in yield and black pod disease incidence (especially PA 150 and PA 7) than the IMC, NA and SCA. The Parinaris have higher general combining ability (GCA) for yield and lower GCA for black pod incidence (Adomako, Allen & Adu-Ampomah, 1999a).

Reaction to important local diseases

The most important diseases that threaten the cocoa industry in Ghana are the CSSVD and black pod disease. The CSSVD is caused by a virus. *Phytophthora palmivora* and *P. megakarya* are the most important species of fungus responsible for the black pod disease of cocoa in Ghana. Economic losses caused by the two pathogens are huge. *Phytophthora palmivora* accounts for a mean annual loss of 18 to 24 per cent (Abdul-Karimu *et al*., 1999; Asare-Nyarko, 1974). Losses due to *P. megakarya* range between 60 and 100 per cent (Dakwa, 1988). Among the measures being used to control the diseases is breeding for varieties resistant or tolerant to the pathogens. One of the most important traits being sought for in the cocoa introductions is, therefore, resistance or tolerance to the two important diseases.

Reaction to cocoa swollen shoot virus disease

Amelonado cocoa is highly susceptible to infection with cocoa swollen shoot virus (CSSV) (Thresh *et al*., 1988). The most virulent strains of CSSV can deteriorate trees rapidly and kill them within a few years of infection (Posnette, 1951; Posnette & Todd, 1955). The susceptibility and sensitivity of Amelonado cocoa to CSSV has been confirmed in laboratory and field experiments (Thresh *et al*., 1988). The local Trinitarios are as susceptible to the CSSV as the Amelonado cocoa. However, the local Trinitarios show some level of tolerance to the virus. In field trials some local Trinitarios produced symptoms that were restricted, inconspicuous, and slow to develop compared with Amelonado. The relative tolerance of some local Trinitarios also showed in their continued growth and lack of defoliation, leaf distortion, and necrosis after infection. The degree of tolerance was, however, considered to be of no economic significance (Thresh *et al*., 1988).

Of the 1944 cocoa introductions from Trinidad, only progenies of Upper Amazon consistently showed higher levels of resistance or tolerance to CSSV than Amelonado progenies (Legg & Kenten, 1968). These included T17/524, T60/887, T65/238, and T65/326. The resistance to CSSV of a wide range of cocoa genotypes has been compared by several workers in Ghana and, invariably, the most resistant were found in the Upper Amazon types (Legg & Kenten, 1968; Kenten & Legg, 1970; Legg & Lockwood, 1977). Of these, the IMC and NA were the most resistant (Posnette, 1981).

The later introductions show a wide range of resistance or tolerance to CSSV, but none has been found to be significantly more resistant than the IMC and NA types of the Upper Amazon population. It seems, however, that the most promising selections from the later introductions, such as SPA 12, UF 713, UF 242, BE 3, EET 353, EET 308, EET 12, VENC 4/4, LF 1 and BE 10, can be used to produce progenies of higher CSSV resistance when crossed with some selected Upper Amazon material (Adu-Ampomah *et al*., in press). The later introductions may have CSSV resistance factors which are different from those observed in the Upper Amazon material (Adu-Ampomah *et al*., in press).

Reaction to black pod disease

Amelonado is generally resistant to the black pod disease caused by *Phytophthora* species (Wharton, 1959; Glendinning, 1964), although some unselected Amelonado types show extreme susceptibility to the fungus and have been used as susceptible controls in an early hybrid resistance trial (Glendinning, 1965). The Amelonado type with the highest level of resistance to the disease is P 30, which was collected from a farm at Kpeve in the Volta Region of Ghana (Posnette, 1943).

The local Trinitarios are generally susceptible to the black pod disease (Lockwood, 1971). However, Wharton (1959) and Glendinning (1965) were able to select resistant types that were used as parents of crosses for the first and second black pod resistance trials in Ghana. The materials selected as being outstanding for resistance to the disease were D70, K5, U6 and Y44 which were collected from farms in Buda in the Bekwai District, Kumasi, Suhum and Anyinam, respectively (Posnette, 1943).

Some progenies of Upper Amazon cocoa types from the 1944 introductions from Trinidad have shown consistent resistance to the black pod disease in the laboratory and in the field (Amponsah & Asare-Nyarko, 1973; Amponsah & Nkulenu, 1994; Abdul-Karimu & Bosompem, 1994; Opoku *et al*., in press). These include T60/887, T79/501 and T85/799. The cross T79/501 × T85/799 (Series IIF) is included in all progeny trials as the standard for comparing black pod resistance. Outstanding and economically important resistance has also been found in other Upper Amazon types – Scavina 6, Scavina 9, and Parinari 7.

Lockwood (1971) has noted that the black pod resistance shown by most cocoa types derives from the fact that they produce most of their crops outside the main black pod epidemic period, from June to mid-October in Ghana. Cropping pattern is, therefore, a major determinant of the level of pod disease losses. These losses in Amelonado have been found to be generally lower than either in the Upper Amazons or local Trinitarios with similar cropping patterns. Moreover, Upper Amazons also have lower pod disease losses than the local Trinitarios with similar cropping patterns (Glendinning, 1966).

Losses due to pod disease in some local Trinitarios were so high that their use as pollen parents in seed production plots was discontinued in the early 1970s (Amponsah & Asare-Nyarko, 1973). However, it has been found recently that the progenies of some Upper Amazons and local Trinitarios recorded the highest yield and lowest pod disease losses in a field trial at Akumadan, an area that has become marginal for cocoa production and also endemic for *P. megakarya* (Abdul-Karimu *et al*., in press). It has, therefore, been suggested that the use of some local Trinitarios, especially Y44, as parents in programmes to develop improved planting material for marginal and black pod endemic areas must be revisited.

In the later introductions, a wide variation in response to the black pod disease infection has been observed (Amponsah, 1981; Adu-Ampomah *et al*., 2004). Three of these materials, PA 150, MA 12 and Pound 7, have shown significantly higher resistance to *P. megakarya* than the best of the introductions from Trinidad. They are now extensively used as female and male (pollen) parents for developing improved planting material for *P. megakarya*-endemic areas like Bechem and Akumadan.

Pod and bean characteristics

Besides other desirable traits, all the introductions need to have pod and bean characteristics acceptable to chocolate manufacturers and farmers.

Bean number

The number of beans per pod of cocoa ranges between 25 and 45. Cocoa progenies of the Upper Amazon and Trinidad introductions generally give higher number of beans per pod than those of the Amelonado and local Trinitarios. Among the Upper Amazon population, IMC and NA families produce pods of higher bean counts than the PA and SCA families.

Bean weight

The dry bean weight of cocoa is 0.9 to 1.5 g. The chocolate manufacturers expect that the dry bean weight of cocoa will be at least 1.0 g (Wood, 1979). Cocoa progenies of Upper Amazon and Trinidad introductions yield beans with dry weights of 1.0 to1.2 g. Amelonado and local Trinitarios cocoa produce beans weighing about 1.1g, similar to that of the Upper Amazons. Among the Upper Amazon population, progenies of SCA usually produce beans weighing less than 1.0 g whilst IMC progenies yield beans weighing over 1.1 g. High bean weights above 1.4 g have been observed in some progenies of the later introductions such as EQX (Adomako *et al.*, 1999b).

Pod value

The pod value of cocoa (the number of pods required to produce 1 kg dry weight of beans) varies between 19.0 and 30.0. The IMC and Trinidad introductions give lower pod values than the NA, PA and SCA. Some later introductions such as EQX have low pod values of 19.0 to 20.0 which are desirable, whilst others such as C-SUL and Rb give high pod values of 27.0 to 29.0 (Adomako *et al.*,1999b) which are unsatisfactory in yield.

Wet-to-dry weight conversion ratio

The conversion ratio of cocoa (ratio of dry weight to wet weight of cocoa beans) ranges from 35.0 to 45.0 per cent (Adomako & Adu-Ampomah, 2003). Amelonado cocoa usually has a conversion ratio of over 40.0 per cent, generally higher than the values for Upper Amazon and Trinidad introductions.

Fat content

The recommended range for fat content of Ghanaian cocoa beans is from 57.0 to 58.0 per cent (Wood, 1979). Beans of Upper Amazon and Trinidad introductions generally have higher fat content (56.0-62.0%) than beans of Amelonado and local Trinitarios (55.0-57.0%) (Adomako & Adu-Ampomah, 2003).

Shell content

The standard for shell content of cocoa beans is between 4.5 and 12.0 per cent (Wood, 1979). Most Upper Amazon cocoa progenies produce beans with shell contents of 14.0 to 16.0 per cent which are above the recommended range. Amelonado and local Trinitario cocoa generally produce beans with lower shell content (12.0-13.0%) (Adomako &Adu-Ampomah, 2003).

Flavour

The flavour of cocoa is largely determined by the process of fermentation and drying of beans. However, because of a genetic component, Amelonado cocoa consistently gives the best flavour as compared to the other introductions. Earlier in the breeding programme in Ghana, some Upper Amazon cocoa types, including T16, T81 and T92, that had unacceptable flavour were eliminated (Thresh *et al.*, 1988). The Upper Amazon and Amelonado cocoa types belong to the Forastero group and, thus, have similar flavour.

Quarantine procedures

In Ghana, cocoa germplasm material is received, *via* intermediate quarantine stations in Europe and America, largely in the form of vegetative material (budwood). After budding onto rootstock, the resulting budlings are kept in a quarantine house for at least 6 months. The budlings are inspected and certified free from any diseases before being planted in the field. Budlings showing unusual symptoms that cannot immediately be associated with any specific biotic or abiotic agents are retained in the quarantine house for further observation. Symptoms associated with budlings not certified for field planting have included stunting and chlorosis.

Earlier introductions into Ghana were sent by air, and the parcels were collected at the airport before being brought to Tafo for budding. To date, all materials have been received in good condition and successfully budded onto rootstocks. However, in 1988, a consignment of budwoods of John Allen's Equador collections sent from the Barbados Quarantine Station was accidentally stored in a refrigerator and was, therefore, exposed to low temperatures at the airport in Ghana. The budwoods were killed and all the 10 clones were lost. The CRIG now relies on visitors to and from the Intermediate Quarantine Stations, especially in Reading in UK and Montpellier in France, to receive germplasm. Loss of germplasm in transit has, therefore, been largely eliminated.

Discussion

Collecting cocoa germplasm material is only the first step in a long process of cocoa improvement programme that should finally lead to developing new varieties of cocoa with higher yields, resistance or tolerance to diseases and pests, and other desirable characteristics. Pound's Upper Amazon collections were widely distributed, notably to West Africa and Malaysia. These collections and progenies derived from them, dating from 1937 to 1943, have formed the basis of cocoa improvement programmes in Ghana, Cote d'Ivoire, and elsewhere (Anon., 1950; Lockwood, 1985; Lockwood, Pang &Ten, 1994; Paulin *et al.*, 1994; Adomako *et al.*,1999a, 1999b). This Upper Amazon material has also proved to be a good source of resistance to CSSVD (Posnette & Todd, 1951; Legg & Lockwood, 1979). The success of the hybrid varieties distributed in West Africa, based largely on the Pound's Upper Amazon collections, suggests that even greater improvements in vigour, yield, and disease and pest resistance or tolerance would be possible if more germplasm collections were provided for use by breeders. The scope is large to increase the genetic base for cocoa breeding. Surveys of wild material should be continued in some Upper Amazon regions, such as Peru or Columbia, with substantial diversity that has not yet been largely exploited.

To be successfully deployed as new parents for genetically improving cocoa, the new introductions must have desirable characteristics such as disease and pest resistance, ability to easily establish in the field, and pod and bean characteristics acceptable to chocolate manufacturers and farmers. The quality factors of cocoa that concern breeders and chocolate manufacturers include flavour, fat content, bean size, and shell thickness.

Amelonado cocoa is the most vulnerable to CSSV of all the introductions tested so far. It is more easily infected than other types and is more severely damaged after infection. However, the beneficial outcome of the extreme vulnerability of Amelonado was that it provided the incentive and impetus for introducing other genotypes and led to the merits of Upper Amazon cocoa types being appreciated. These now have an important role not only in West Africa, but also in producing countries where the CSSVD is uneconomically important.

Over the last 40 years in Ghana, there have been great changes in the types of cocoa being grown. The shift from West African Amelonado to the various Upper Amazon derivatives will undoubtedly continue.

An investigation on seven cocoa breeding trials at Tafo and Apedwa in Ghana to find out the factors that limit the yielding capacity of Upper Amazon hybrids showed that hybrids which recorded the lowest yields were, invariably, intra-population crosses, indicating the effects due to inbreeding depression (Adomako & Adu-Ampomah, 2000).

Yield is the result of balanced biochemical and physiological processes, and that either deficient or excessive activity of a component could detrimentally affect yield (Fasoula & Fasoula, 2000). Thus, maintaining adequate genetic variability with desirable traits in cocoa germplasm collection is essential for improving cocoa. With the introduction of several non-Pound's Upper Amazon accessions now at CRIG, the problem of inbreeding can largely be avoided in future breeding programmes.

Because there is the risk of accidentally introducing pests and diseases along with cocoa germplasm material, the importance of constructing proper quarantine houses and effective indexing procedures in individual cocoa-producing countries cannot be over-emphasised.

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