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Agronomic research on cocoa in Jamaica 1950-1980 and current research trends

H.J. Fagan and B.F. Toppert*

Faculty of Agriculture Unit, University of the West Indies, Mona, Jamaica, W.I.

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Agronomic research in cacao in the 1950s in Jamaica was devoted almost entirely to the introduction, propagation and establishment of different varieties imported mainly from Trinidad and St Vincent. Field evaluation of these introductions led to the adoption of a few medium- to high-yielding varieties, but the later discovery of their susceptibility to black pod disease [*Phytophthora palmivora* (Bull.) Bud.] restricted their use as parents in breeding programmes. The resulting germplasm base of the cocoa industry is very narrow. However, the observed slow growth of the pathogen in the pod tissues of the susceptible variety ICS 60 permitted its use and resulted in the production of PA 150 - ICS 60 as the best-yielding local hybrid. Nutrition experiments dealt mainly with the effects of N, P and K on yield of cocoa cultivated with or without shade, and with liming of acid soils. but no experimentally determined fertilizer recommendations ensued. New fertilizer experiments aim to address this, and other current research seeks to broaden the germplasm base of the cocoa industry and to re-evaluate a cocoa/coconut intercropping system.

Keywords: Cacao: Jamaica

Cocoa (*Theobroma cacao* L.) has been grown in Jamaica since the 17th century (Fagan, 1984), but although it was in Jamaica that F. Harris pioneered the successful budding of cocoa by his patch budding technique in 1902 (Van Hall, 1914), very little agronomic research was undertaken there until the late 1940s; patch budding had not been adopted. The improvement of Jamaican cocoa germplasm relied heavily on results of research undertaken at the well-established former Imperial College of Tropical Agriculture (I.C.T.A. - now the Faculty of Agriculture of the University of the West Indies) in Trinidad.

There has been a long history of cocoa research at I.C.T.A. where Pyke in 1935 first developed the method of cocoa propagation by rooted cuttings (Topper, 1957a). The renowned Imperial College Selections (ICS vacs) of cocoa from that regional institution were made readily available in Jamaica. Thus, in 1942, several of these varieties, ICS 1, ICS 6, ICS 8, ICS 45 and ICS 98, were established in Jamaica from budwood obtained from Trinidad (Anon, 1977). All but one of those selections were Trinitario cocoa (hybrids resulting from crosses between Forastero and Criollo types of cocoa). The exception, ICS 45, was a true Criollo selection.

Cocoa had been regarded as an economically minor crop until the late 1940s when a new thrust towards improving the cocoa industry in Jamaica commenced. In 1947, the Jamaica Department of Agriculture initiated steps for rehabilitating local cocoa cultivations, following the assurance of a ready external market for all the cocoa that could be produced, and recommendations from a 1945 agricultural report on the centralization of cocoa processing on the island. In 1948 the first agronomist to the industry was appointed (Fagan, 1984), and in 1949 a scheme for the expansion of the cocoa industry was approved (Anon, 1950b), which ambitiously aimed at cultivating 20 243 ha (50 000 ac) in 10 years. Almost 40 years later, this ambition is yet to be realized.

* Present address: WINBAN, PO Box 115, Castries, St Lucia, W.I.

+ Cocoa Industry Board, Marcus Garvey Drive, PO Box 68, Kingston 15, Jamaica, WI

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Cocoa introductions and multiplication of germplasm

Adding to the earlier introductions from Trinidad, budwood of two of the currently highest yielding varieties in Jamaica, namely, ICS 60 and la 95, was imported from St Vincent in 1950 (Anon, 1950a, 1951), and a further eight varieties (GS 29, GS 36, ICS 16, ICS 32, ICS 39, ICS 40, ICS 46 and ICS 84) were imported from the same source in 1956 (Topper, 1957b). In 1957, five more varieties were introduced from Costa Rica, and eleven from Mexico.

Work over the next several years consisted essentially of the multiplication of the introduced varieties by budding, and the propagation of local clones by rooted cuttings. Rooted cuttings of several new varieties were also imported from Trinidad in 1959. These included IMC 57, 1MC 67, PA 30, PA 46, PA 81, PA 121, PA 150, PA 169, PA 218, SCA 6, SCA 9, SCA 12, TSA 644 and TSH 556 (Dow, 1960), some of which are now parents of important hybrid material, and others growing commercially.

Initial technical difficulties encountered in the production of rooted cuttings hampered the propagation drive. These difficulties arose partly from lack of experience in the relevant techniques and partly from the apparent paucity of relevant information then available in the literature (Topper, 1957b). In attempting to overcome these difficulties, a number of small-scale exploratory experiments had been conducted earlier. From such experiments it was determined that a 500 ppm β-indolebutyric acid (I.B.A.) dip of the cuttings produced the best rooting results among various growth-promoting substances tested (Anon, 1951). Some success had previously been obtained also in selecting a satisfactory potting medium and in air-layering (marcottage) (Anon, 1950b). These successes were important advances for undertaking clonal propagation by rooted cuttings on a substantial scale.

During those early years of establishing a germplasm base, while at the same time providing planting materials for an expanding cocoa industry, a rapid expansion of cuttings gardens was undertaken, but with the use of *Gliricidia* sp. as the main source of overhead shade, the long period required for the development of a satisfactory shade canopy resulted in poor establishment of the nurseries. Further, the occurrence of high pH in the soils of some nurseries (sometimes due to presence of free lime) also retarded growth of the young plants. The edaphic difficulties were alleviated to some extent by various cultural and exploratory treatments (Anon, 1951).

By 1956, a large number of local seedlings were being produced in the nurseries, facilitating a novel system of 'budding-at-stake' (budding of seedlings already transplanted in the field), using a method of T-budding developed by Topper (1957a). However, budding-at-stake subsequently failed due to extreme shortage of supervisory extension personnel in the Department of Agriculture, and to high cost of field maintenance (Topper, 1957b; Dow, 1960). The T-budding technique succeeded and was employed in producing over 130 000 plants, these being grown in improvised pots made of intemodes of large bamboo stems as a cost-reducing system.

Despite the continued popularity of rooted cuttings as planting material, by 1959 it had become more practical to distribute hybrid seedlings to growers. This was prompted partly by recent information from researchers in Ghana and I.C.T.A. in Trinidad that hybrid seedlings resulting from crosses between Forastero or Trinitario cocoa and some wild cocoa varieties from the Upper Amazon basin were more vigorous and hardier planting material than rooted cuttings (Anon, 1977). About 1960, a programme was started for producing hybrid seeds locally by hand pollination and open pollination of a selected number of parents. Among the important female parents used were IMC 67, SCA 12, PA 150 and PA 169; the most widely used male stocks were ICS 1, ICS 6, ICS 8 and ICS 60 (Anon, 1964). The open-pollinated hybrids (the most readily available planting material) were obtained from the earlier interplanting of PA 150 with ICS 60 and, separately, with ICS 1 in a seed garden (Anon, 1977). Thus, from 1961 an appreciable number of hybrid seedlings were produced in Jamaica, thereby reducing importations of materials from Trinidad. Over 200 000 open-pollinated hybrid seedlings are currently obtained from the seed garden annually.

The emphasis hitherto had been on high-yielding selections, but with the discovery by Leather (1964, 1966) of high susceptibility to black pod disease (Phytophthora palmivora (Bud.) Bud.) in some of the female parents used in the breeding programme, modifications were effected in the programme. Thus, the large-seeded and vigorous but susceptible IMC 67 variety continued to be used, but only for seedlings to be distributed to areas with low disease incidence. The use of the susceptible SCA 9 and SCA 12 female

parents was discontinued although they were believed to confer a distinctive and desirable flavour called `arriba' to their progenies (Anon, 1964).

Research findings in Trinidad and elsewhere had shown that cocoa may yield better under reduced shade (Murray and Herklots, 1955; Cunningham et al., 1961) and that low shade was also conducive to low humidity which is less favourable for black pod disease development (Dakwa, 1974, 1977; Vernon, 1966; Rocha and Machado, 1972). It was therefore correctly argued that removal of overhead shade would reduce the incidence of black pod disease in Jamaica where susceptible progenies were being grown.

Differences in susceptibility to black pod of some of the introduced varieties from Trinidad were confirmed by Spence (1961) shortly before Leather's (1964) discovery of differential susceptibilities under Jamaican conditions. Disease reactions of the same varieties differed between isolates of *P. palmivora* from Trinidad and those from Jamaica; while in Trinidad the Scavina varieties (e.g. SCA 6) were found more disease-resistant than ICS 1 (Spence, 1961), in Jamaica the reverse was found to obtain (Leather, 1964, 1966). The contrasting reactions probably resulted from differences between the strains of *P. palmivora* occurring in the two localities.

Of 39 clones and hybrids subsequently tested (including 17 Jamaican hand-pollinated crosses), appreciable resistance to black pod disease was reported only in ICS 1 and PA 169 in the imported clones, and in JH 10 and JH 17 from the local hybrids (Henry, 1973, 1974). The presence of disease resistance in so few of the tested materials reduced the scope for further field resistance trials. However, a trial was set out in 1972 to evaluate four locally-produced hybrids of some introduced varieties for susceptibility to disease and for desirable agronomic properties (especially bean size and yield). After nine years of evaluation, it was concluded that disease reactions were variable and dependent on weather conditions. The hybrid PA 169 x ICS 1 was found to yield the least, and PA 150 x ICS 60 the most (Reid, 1981).

Varietal trials

The first recorded variety trial was planted in 1949, but it was abandoned after two years due to difficulties in establishing adequate shade and in obtaining a suitably uniform stand of cocoa (Anon, 1951). A new variety trial was started at Orange River Agricultural Station in 1952 using local and introduced varieties grown under banana as temporary shade and *lnga vera* (Willd.) as permanent shade (Topper, 1953). After 10 years, and following the removal of all overhead shade during the preceding three years (Topper, 1964), the yields of the different varieties were finally resolved into three groups: (A) high yielders: ICS 60 and ICS 6; (B) medium yielders: ICS 8, ICS 1, ICS 98 and ICS 95; and (C) low yielders: JCV 1, JCV 2, JCV 3 (all local germplasm) and ICS 45.

Despite the favourable response of ICS 6 and the acceptable performance of the varieties in group B, only ICS 1 and ICS 60 were subsequently actively propagated for distribution, due to the high susceptibilities of the other varieties to black pod disease (Anon, 1977). Despite the known susceptibility of ICS 60, it had been observed that there was a relatively slow invasion of the pod tissues by the pathogen; consequently, many infected pods were still marketable. Thus, ICS 1 and ICS 60 are currently the two most widely grown varieties, although a number of other varieties, e.g. ICS 95, ICS 98 and ICS 6 are also found in commercial quantities.

Nutrition studies

Studies in cocoa nutrition were all conducted at the Orange River Agricultural Station near Highgate in the cocoa-producing parish of St Mary. Highgate clay, a particular category of soil which occurs on the predominant lesser slopes of the agricultural station, is known to be extremely acidic (Anon, 1975b), with pH values often reaching 4.7 or lower (Harrison and Miller, 1976; Fagan, unpublished data).

The first recorded fertilizer experiment was established in 1961 using three-year-old 1MC 67 trees with Musa cvs. as temporary shade and Gliricidia sp. as permanent shade (Prendergast, 1962a). The major nutrients, nitrogen as ammonium sulphate, phosphorus as triple superphosphate, and potassium as muriate of potash were applied at different rates and in mixtures. After eight years no significant differences between treatments were evident (Anon, 1975a). However, a trend emerged indicating that whereas variable responses to N and P were obtainable, there was consistently no response to K, explained by the high levels of K found in the soil at that site (Harrison and Miller, 1976; Fagan, unpublished data). The low

response to N was later shown to be associated with the negative effect of shade on yield of cocoa.

During the earlier years of the cocoa industry in Jamaica, the crop was always grown under permanent shade. The responses of cocoa under shade to fertilizer application had not been specifically examined locally. With the start of the major expansion scheme in 1949, it was considered expedient to investigate such response of rooted cuttings growing under shade (Anon, 1975d). However, such an experiment was not started until 1963, using ICS 95 and ICS 60 growing in a mixed stand at the Orange River Agricultural Station with and without permanent shade. This trial differed from the preceding trial of 1961 mainly in the introduction of a no-shade treatment and in the planting materials used. Yield responses in the no-shade plots started to emerge after the third year, but increases were essentially in response to N, the lower level of which produced better than the higher (Anon, 1975d). Neither phosphate nor potash by themselves gave any significant increases in yield. In the shade environment, no significant response to any of the major nutrients emerged during the first four years. However, favourable interactions between phosphate and the other major nutrients indicated a definite advantage in a mixed fertilizer. Thus N_1P_2 and N_2P_2 were significantly ($P = 0.05$) better than N_1P_1, N_2P_1 and N_2P_0; and P_2K_2 was significantly ($P = 0.01$) better than P_1K_1 and P_2K_1 (Anon, 1975d). In a concurrent observational trial using unreplicated one-acre (0.41 ha) plots each of shaded and unshaded ICS 1 cocoa, the yield of beans in the unshaded plot was 40.5% higher than in the shaded for the eight years 1966-1974 (Anon, 1976).

These results supported to a large extent earlier findings (Murray and Herklots, ibid.) that under increased light intensity, responses to N fertilizers, in particular, increased and there was little response to nutrients under shade.

The effect of liming on fertilizer responses of cocoa in highly acidic soils was tested 1969-1974 in an observational trial in which lime (crushed marl) at different rates was incorporated into the soil. There followed increases in foliar Ca, soil pH and available P, and a 77% increase in yield (Harrison and Miller, ibid.). This marked the end of cocoa nutrition trials in Jamaica for the period reviewed, although no derived recommendations had been forthcoming. However, a nitrogen-fortified NPK fertilizer (16-9-18 plus ammonium sulphate) has been in use on cocoa in Jamaica for some years, at the recommended annual rate of 0.69 kg (1.5 pounds) tree each of 16-9-18 and of ammonium sulphate, in two equal applications. No liming recommendation has been issued and liming of cocoa is not practised.

Pruning experiments

A trial to investigate the effects of different pruning regimes on production was established in 1961, using open-pollinated hybrid seedlings of PA types of cocoa initially growing under shade (Prendergast, 1962b) but without shade after six years (Anon, 1975c). At the 8th year, pruning of trees to leave one jorquette with five fan branches yielded significantly more wet beans ($P = 0.05$) than no-pruning, and black pod disease levels were significantly lower with that regime than in unpruned plots (Anon, 1975c).

Intercropping experiment

An experiment was started in 1972 to determine what gains in productivity and income could be derived from interplanting cocoa with established Malayan Dwarf coconut palms. The experiment also attempted to evaluate different hybrid materials (e.g. PA 150 x ICS 1, PA 150 x ICS 60 and PA 169 x ICS 60) and different planting distances for cocoa in the system (Clemetson, 1975). Yield data recorded after four years indicated that: (a) closer spacing yielded more cocoa as a result of higher plant population densities; (b) hybrids with ICS 60 as a parent were the more productive (Clemetson, 1978; Btarrant, 1978), yielding 20% more cocoa than those with ICS 1 parents (Anon, 1979). Quite apart from the effect of preceding drought, the yield recorded later at six years was quite low, and supported earlier indications that interspecific competition between coconut and cocoa occurred (Anon, 1979). The trend in hybrid productivity was confirmed in a concurrent hybrid seedlings trial at another location, involving ICS 60 and ICS 1 hybrids growing in monoculture cocoa, when hybrids containing ICS 60 female parents yielded 16% more cocoa than those with ICS 1.

Current research trends

Recent agronomic research on cocoa in Jamaica has reflected priorities placed in five main areas of

investigation, (i) fertilizer experiments towards an updated recommendation for the industry; (ii) introduction and evaluation of high-yielding blackpod-resistant planting materials; (iii) re-evaluation of cocoa/coconut intercropping; (iv) re-evaluation of cocoa spacing; (v) resuscitation of cocoa propagation by budding.

Fertilizer experiments

With the recognition of an urgent need for an experimentally tested fertilizer recommendation for cocoa in Jamaica, two experiments were initiated in 1983. One was conducted on 20-year-old rooted cuttings (mainly ICS 1, [CS 60 and ICS 95 in a mixed stand) located at Orange River Agricultural Station, and the other on 10-15-year-old hybrids of mixed parentage, located at Montrose in the Richmond Valley of St Mary. Although classed as basically the same soil type (Belfield clay), these two sites differ in soil reaction and physical composition (Orange River: 40.7% sand, 51.1% clay and acidic; Montrose: 66.1% sand, 23.8% clay and neutral to alkaline). One fertilizer treatment was an analytically determined recommendation based on foliar and soil analyses of samples from the sites. This recommendation was compared with available pre-mixed NPK fertilizers (some used in local coconut production), including 16-9-18 + ammonium sulphate (the current recommendation for cocoa). Yield data obtained after the first two years indicated that the best treatment at both sites is the pre-mixed NPK fertilizer 12-10-18 applied at the rate of either 0.45 kg or 0.9 kg (1 or 2 lb.) tree^{-1} annually in two split applications.

New plant introductions

A need for broadening the germplasm base of the Jamaican cocoa industry has been recognized. Importation of hybrid seeds from Trinidad was resumed, and batches of high-yielding and blackpod-resistant TSH selections were received between 1982 and 1984 (Fagan, 1984). These seedlings are being evaluated at a new agricultural station (Montpelier, in St James parish), away from established cocoa-producing areas, as a precautionary measure against any possible introduction of witches' broom disease (*Crinipellis pemiciosa* (Stahel) Singer) which occurs in Trinidad.

Renewal of budding in cocoa propagation

The method of propagation of the moderately black-pod-resistant (locally considered the most resistant) and popular ICS 1 variety is usually by rooted cuttings. However, the supply of such planting material has been persistently limited by various difficulties in its production in Jamaica over the years. The alternative method of propagation by budding was therefore reconsidered after a lapse of interest in this method, and a programme for reviving this method was initiated in 1983. The main rootstock being used is IMC 67 which was chosen for the vigour of its seedlings, but other potential rootstocks such as [CS 60 and PA 150 have been included. With the anticipated success of this programme and subsequent training of personnel in budding techniques, it is envisaged that large quantities of promising varieties of cocoa will be produced for a reviving cocoa industry.

Cocoa/coconut intercropping

An experiment to evaluate the feasibility and desirability of interplanting cocoa with Maypan hybrid seedlings of coconut (now the recommended planting material in Jamaica against Lethal Yellowing disease) was started at Montpelier Agricultural Station in 1984. Besides testing the performance of the two crops, the experiment also attempts to compare the two most popular types of cocoa planting material, rooted cuttings and hybrid seedlings, in the intercropping system. The clone being tested is ICS 1 and the seedlings are ICS 60 x PA 150. These materials are being tested at three spacing distances, 1.8, 2.7 and 3.7 m (6, 9 and 12 ft) along the row, between young coconut seedlings planted at a constant spacing of 6.3 m (21 ft) on a triangular pattern. Plantains (Musa cvs.) were used as temporary shade for the young cocoa plants, with the objective also of providing a readily marketable cash crop in the early years of the cropping system.

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