Coconut Hybridization by the Policaps and Mascopol Systems

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The POLICAPS system for coconut hybridization uses individual POLyurethane Isolation CAPS to protect each female flower from unwanted pollen. Policaps have advantages over the large bags of plastic, terylene, or heavy canvas that have previously been used to isolate the inflorescence. Using this new system the time for pollination can be judged from ground level without the need to climb the palm or disturb the isolated flowers. The method of pollination positively ensures that pollen is applied to the stigmas and identifies which female flowers have been pollinated and which have not. With the policaps system the female flowers are not exposed to the high temperature and humidity that can occur in isolation bags, and indeed the policaps insulate the female flowers from extreme conditions. All these advantages should lead to improved fruit set from controlled pollinations.

The MASCOPOL system, or MASs COntrolled POLlination, does away with the need to isolate individual flowers or inflorescences by establishing the whole seed garden in an isolated area or by surrounding it with a screen of foliage. The application of large amounts of pollen to large numbers of emasculated palms produces hybrid seed in commercial quantities. The mascopol system allows a new hybrid to be produced simply by bringing a different pollen to the seed garden.

The policaps and mascopol systems complement one another. Policaps will be used on selected, individual palms from desirable, cross-pollinated cultivars to produce improved progenies; these will in turn provide pollen for mascopol hybrid production. It is intended that sufficient information be available here to encourage others to take a practical interest in coconut breeding.

The Coconut Palm

Unlike the oil palm, the date palm, or many other crops, the coconut palm produces very few seeds on one inflorescence. However, new inflorescences open at approximately monthly intervals throughout the year and a continuous pollination program can be maintained.

Each inflorescence bears both male and female flowers (Fig. 1). For hybridization the male flowers must be removed (emasculation) and the female flowers must be kept free from contaminating pollen (isolation) until the correct pollen for the particular cross is supplied (pollination). These three operations, emasculation, isolation, and pollination, which are the elements of controlled hybridization, have been understood and practiced by coconut breeders for many years. Recent innovations in pollen collection, storage, and application have now liberated the coconut breeder from the limitations of low seed set by allowing him to increase the number of palms which are pollinated. The commercial production of many different F_1 hybrids is a major factor in modern agricultural development schemes in countries where coconuts are grown.

1. A coconut inflorescence.

The quality of the F_1 hybrid is determined by the two parents. Improvement within a parent type and eventually, perhaps, the development of a true-breeding cultivar as good as the F_1 hybrid, calls for controlled hand-pollination of selected individuals. Here the availability of large quantities of pollen is not essential. What is needed is the ability to set an optimum number of seeds on any one

pollinated inflorescence. While investigating the factors that control the number of nuts carried on any one bunch, an improved pollination technique was developed.

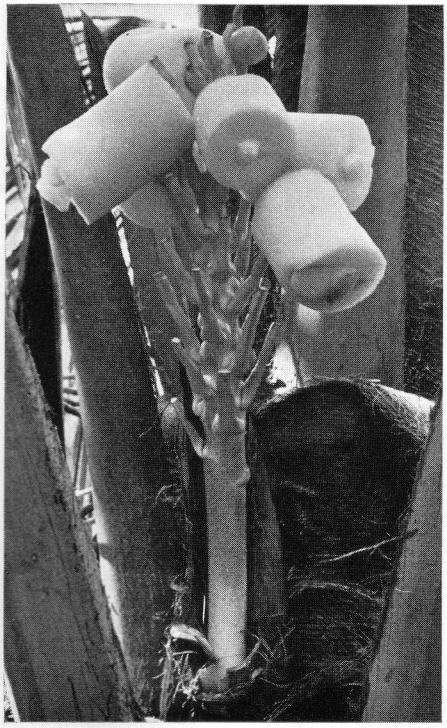
The Policaps System

Emasculation

Unless the male flowers are needed for pollen collection (see below), the best time for emasculation is the day before the inflorescence would normally emerge from its spathe. This can be judged, with experience, from signs such as the bulges at the bottom of the spathe (caused by the developing female flowers), the widening of the longitudinal groove (which is the point of weakness along which the spathe naturally splits), and the loss of the fresh color from the tip of the spathe.

At this stage the tip of the spathe is cut off with secateurs and the point of the blade is used to split the spathe vertically into two or three strips. These are cut off as low as possible. If emasculation is done a week later, when the male flowers are sufficiently developed for pollen collection, the spathe will have dried considerably and is then more difficult to remove. The inflorescence that is exposed by early emasculation is tender and must be handled carefully. The female flowers may not develop if they are damaged and the junction of the branchlets with the main inflorescence stalk is likely to tear.

Sometimes a few male flowers near the tip of the inflorescence may have opened within the spathe before it is split. The risk of pollen contamination from these is slight since the female flowers are not yet receptive. All male flowers are removed by cutting each branchlet 2–3 cm. above the female flowers. Male flowers also occur at the base of female flowers and it is essential to pick these off by hand. Branches without female flowers are completely removed. Other branches may have one, a pair, or more female flowers. Since policaps are intended to cover single flowers, any twin flowers are removed (although it would be possible to make suitable twin policaps). Damaged, insect-infested, or deformed female flowers are removed. If a very high number of female flowers are present, they can be reduced in number since pollinating all of them might require more than two or three visits. If 30 or more nuts are set, these become so heavy that they can pull the bunch out of the leaf axil before it is mature.



2. Policaps in place on all female flowers but one of an emasculated coconut inflorescence.

Isolation

All but one of the remaining female flowers are covered with policaps, which

should fit in place when slightly stretched (Fig. 2). Since different cultivars and different growing conditions affect the size of the female flower, no exact measurement will be given here; policaps of different sizes are easily made (see below). As the female flowers develop, their increase in size ensures that the policaps fit even more securely. The female flower which is not covered should be one that can readily be seen from ground level. When the policaps have been fitted, the date is marked on the petiole subtending the inflorescence and all of the male flower stalks are collected and disposed of (see below). None must be left in the leaf axils.

Pollination

When the inflorescence opens, each female flower continues to develop and after about two weeks the ovary begins to emerge between the close-pressed perianth lobes. The exact time for pollination receptivity depends on the cultivar and the growing conditions and occurs when the three-pointed stigma is reflexed, moist, and white. Nectar is produced at this time. If isolation bags are used, receptivity cannot be observed and has to be guessed at, the palm climbed, and the bag opened. With policaps the stage of receptivity of the female flowers can be seen from the one which was not covered (Fig. 3). Only when it is becoming receptive, need the palm be climbed. The other flowers are then inspected by removing and replacing one plug at a time. Each receptive flower is pollinated. The bunch is labelled, on the occasion of the first visit, with a tag identifying the pollen parent *and the exposed flower is cut off.*

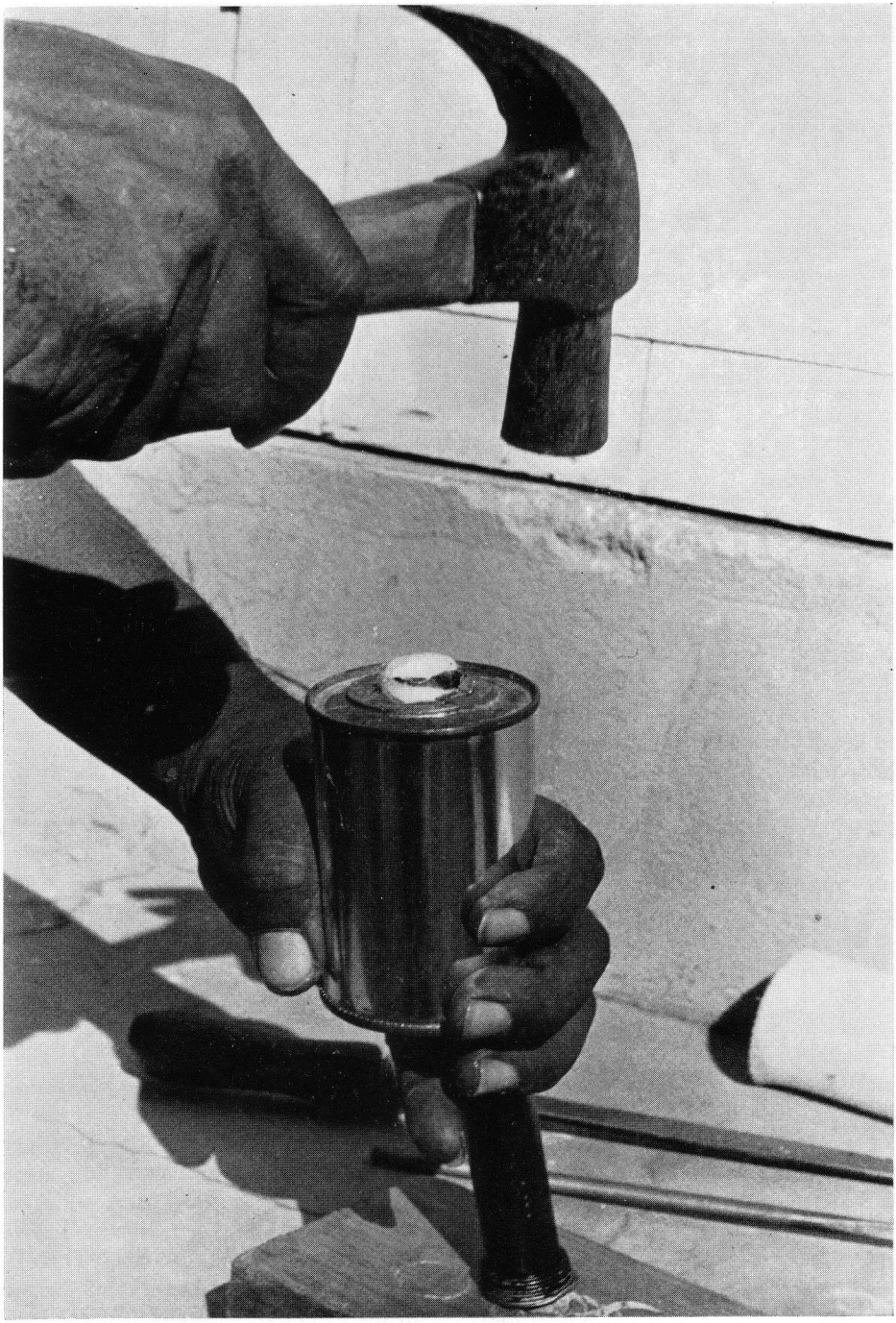
For pollination it is convenient to collect pollen in advance and store it. In this way a fresh supply of pollen can be taken each day in a small, semiopaque vial, stoppered with a polyurethane policaps plug and kept out of the direct sun. When a receptive female flower is found, the plug is removed from the policap, and the pollen vial is shaken to deposit pollen on the end of its plug. This is then removed from the vial and pushed into the policap to bring the pollen in contact with the receptive stigma. The projecting end of the plug is tucked well into the policap to hold it firmly, and the plug that was removed from the policap now serves to close the vial and act as a pollen brush for the next receptive female flower. When there are many flowers on an inflorescence, they will not all be receptive at the same time, and second and third visits may have to be made. On these later visits, to avoid disturbing the pollinated female flowers, the different positions of the plugs serve to distinguish unpollinated from pollinated flowers. Before pollination the plug should be folded into a U-shape in the policap thus exposing the two ends. After pollination, both ends of the plug are tucked well into the policap.

Coconut palms flower regularly throughout the year and it is often possible to take fresh pollen from one palm to use immediately on others. A convenient way to do this is to pull off a handful of male flowers from an unemasculated bunch which has been open for a week or two and, cracking each flower between finger and thumb, drop them into a 10% sugar solution in a small plastic bottle. The bottle has a cap with a small hole or tube through which drops of sugar solution carrying suspended pollen can be directed onto each receptive stigma. This method is convenient where only a few pollinations are to be made or when a small quantity of pollen has to be extended. It is important to remember that the pollen will begin to germinate in the sugar solution and will only be viable for a few hours before it must be discarded.

3. Exposed female flower becoming receptive.

If during a visit it is seen that a policap has fallen off due to wind, rats, or careless placing of the ladder, the flower concerned should be cut off. Contrast this with damage to an isolation bag where the entire inflorescence has to be sacrificed. If after two or three visits a sufficient number of pollinations have been made and a few flowers remain, these may be cut off to save a further visit.

At a later visit to the same palm to emasculate or pollinate the subsequent inflorescence the policaps may be removed. The developing fruit will have expanded the hole in the policap and it will be stiff with dry nectar. It can be washed for reuse or discarded. Records of emasculation, isolation, pollination and, in due course, of nuts reaped, can be made daily in a pocket notebook. To check on the emasculator's efficiency,



4. Making policaps.

occasional bunches can be left unpollinated or pollinated with dead pollen.

When changing from one pollen type to another, it is essential to avoid cross contamination. Hands, arms, and equipment may be safely sprayed with 70% alcohol or a 10% solution of calcium hypochlorite (bleach), which will kill pollen. Some workers may also feel that the female flowers should be similarly treated before the policaps are put on but since pollen is only viable for a day or so, this should not be necessary when policaps are put on two weeks before females are receptive. However, if the bunch is being used for pollen collection, which is not done until the inflorescence has been open for one or two weeks, the later isolation allows a risk of pollen contamination and, therefore, requires sterilization, for which alcohol or bleach is quite suitable.

Making Policaps

Soft polyurethane foam is widely used commercially for packing and insulation and domestically for mattresses and furnishing and it can be cut easily. A suitable size is 5 cm. × 5 cm. × 7.5 cm. long but this can be changed as necessary, perhaps to make use of factory offcuts.

To make a hole in the foam any metal tube of suitable diameter (approximately 2–3 cm.) can be used, the diameter depending on the size of the female flower of the particular variety to be isolated. The block of foam is compressed against the end of the tube (a suitable holder may be made from a can) and struck sharply with a hammer around the circumference of the tube, cutting the foam (Fig. 4). The metal tube needs to be kept in good shape and smoothed with a file, but a sharp edge is not essential. The plug of foam removed is folded into a U-shape and replaced to make the policap ready for use.

Control of pests

Small ants may find a way into policaps when nectar is being produced. If no male flowers are present on any inflorescence of the palm, then the risk of accidental pollination is negligible. Nevertheless, to eliminate ants, cockroaches, and eryophid mites the policaps need only to be soaked in an insecticide such as chlordane and allowed to dry before use. Rats may also be attracted to the nectar and rats or squirrels may sometimes take the polyurethane for nesting purposes. They can be controlled by baiting.

The emasculator/pollinator can also be a source of trouble if he carelessly knocks off or damages maturing fruit. It is also possible that, if a long ladder is used in a young tree, damage done to the young spear leaves by the end of the ladder can cause the bud to rot.

The Mascopol System

The mascopol system, or mass controlled pollination in Jamaica, is essentially the same as "pollination assistée" in Ivory Coast. Hybrids are produced in commercial quantities by blowing or dusting pollen onto the receptive female flowers of some hundreds or thousands of palms daily (Fig. 5).

Isolation

Individual isolation of so many female flowers would be prohibitively expensive. Isolation is achieved by planting the seed garden in an area where no other coconuts grow or by surrounding it with a screen of foliage. This screen should be 200 to 300 meters wide, and it can consist of other tree crops or even emasculated coconut palms. This last method is less satisfactory but because of the extensive nature of coconut plantings it may have to be commonly adopted. These emasculated guard rows

5. Mascopol pollination. Photo by Wendy Hunt.

should be pollinated with the same pollen being used in the seed garden, but unless suitable color markers are involved, the resulting fruit may be suitable only for copra (see color markers).

Emasculation

For the mascopol system, emasculation is done in the same way as described above for the policaps system. There is no need to remove twin or excess flowers

as long as the male flowers around these are removed. Since the female flowers are not individually isolated, it is essential that emasculation be done efficiently so that no inflorescence is allowed to open and shed pollen and no single male flower is overlooked. One male flower produces thousands of grains of pollen. Although only some of the palms need to be emasculated on any one day, and the number depends on the time of year and the prevailing weather, all palms in the seed garden have to be inspected for six days out of seven. If done properly, no inflorescence should open on the seventh day. Allowance must also be made for working during public holidays. One man may be made responsible for about 400 six-year-old palms. Again, the exact number will vary with the season and also with the terrain over which ladders have to be carried.

The male flowers removed at emasculation must be disposed of. On sandy soil this can be done by burying them. Burning is difficult, because the material is fresh and cannot be dried before burning since pollen may be released. Bottomless steel drums with lids can be used. When full, the drum is dragged to one side to allow some of the decomposing flowers at the bottom to spill out. There must be enough drums to hold the male flowers long enough for them to decompose, and the lid must be kept in place at all times to prevent insects visiting and then carrying pollen back to the emasculated palms.

Pollination

At certain times of the year, one bunch is ready for emasculation when another on the same palm is just receptive. The emasculator can, therefore, be supplied with a hand pollen-blower with which to pollinate these. Otherwise, pollination is carried out as a separate operation by blowing a pollen:talc mixture (1:8 parts by weight) from a hand-held blower operated from the ground. If pollen is in short supply, then hand application of undiluted pollen to individual female flowers will give excellent fruit set, but it does involve increased labor costs. To produce a different F_1 hybrid combination it is best to prepare two to three weeks in advance by clearly marking newly emasculated inflorescences with colored ribbon or a splash of paint. One week before these marked inflorescences become receptive, all pollination is discontinued. When the female flowers on these inflorescences become receptive, pollination is resumed using the new pollen parent.

Reaping Seed

Coconut fruit does not mature until 11–15 months from pollination, depending on cultivar and season. Apart from the inflorescence branchlets that were shortened or removed during emasculation, the pollinated inflorescences look no different from normal bunches nor do the reaped fruit (seednuts) look any different. It is not until germination and subsequent growth that hybrids can be recognized (see color markers below). On the first sign of the fruit maturing, when they begin to lose their fresh color and turn dry brown, the policaps-pollinated nuts should be carefully reaped by hand, marked according to the tag on the bunch, and set in nursery beds similarly identified. Mixing of seed or young plants can lead to confusion that will undo all the careful work of the pollinator a year before. Mascopol nuts can be reaped by the bunch instead of individually since they will all be of one type. However, when changing from one hybrid to another, as indicated by the marked bunches (see above), care should be taken to see that the bunches marked differently are set separately.

Table 1. Color inheritance in hybrid seedlings of coconut (simplified).

SEED PARENT	POLLEN PARENT				
	Yellow	Red	Green	Bronze	
Yellow	Yellow	Red	Green	Bronze	
Red	Red	Red	Green	Bronze	HYBRID SEEDLINGS
Green	Green	Green	Green	Bronze	
Bronze	Bronze	Bronze	Bronze	Bronze	

Choice of Parents

On the basis of present knowledge, the most suitable F_1 hybrids will be those resulting from a cross between selected dwarf and tall parents, since these will combine the precocity and high nut number of the dwarf with the larger nut size and robustness of the tall. If the 'Malayan Dwarf' is used, then the hybrid will have some resistance to lethal yellowing disease, the level depending upon the male parent.

Color markers

Accidental self-pollination, or pollen contamination due to inefficient isolation, could possibly go unnoticed for five years or more until the presumed hybrid plants come into bearing. Fortunately, this can be largely prevented by making use of the knowledge of color inheritance when choosing parent palms. The colors referred to can be identified on leaf stalks of seedlings and mature palms and on developing fruit, and are shades of yellow, red, green, and bronze, which can be easily distinguished with a little practice. The dwarf is either yellow, red, or green, and the tall is either green or bronze (the exceptions to this general rule need not confuse us here).

In crosses involving two different colors, one color predominates in the hybrid as shown in Table 1.

The table is simplified in so far as it does not take into account the fact that all colors except yellow can be either homozygous, i.e. they breed true for the particular color, or heterozygous, i.e. they produce plants mainly one color but with a proportion of one of the other colors. Intermediate shades are also found. For the purposes of this introduction to coconut hybridization, it is sufficient that either the yellow or red dwarf forms be chosen whenever possible as the seed parent. In this way, seedlings produced by accidental self-pollination or contamination from other dwarfs can be distinguished from dwarf × tall hybrids as soon as they germinate in the nursery. Green dwarf is less satisfactory as a seed parent, because confusion may arise if hybrids are likely to be green as a result of the pollen parent color. Contamination from neighboring tall varieties, if these are not the same as the tall pollen parent that is being used, *will not* be recognizable in the nursery so that close attention must be given to effective isolation in such situations.

Other advantages are gained from using a dwarf seed parent, because it comes into bearing early, does not grow out of reach as quickly, and is capable of producing a high number of nuts.

In contrast to the advantages of the dwarf as a seed parent, the greatest disadvantage of using the tall as a seed parent is simply that seed from all pollinations, whether legitimate hybrids, contamination from foreign pollen, or accidental self-pollination, will germinate

to show the dominant tall color and no selection will be possible in the nursery.

Apart from F_1 hybrid production, breeding work may involve crossing tall × tall or dwarf × dwarf where color inheritance cannot always be of assistance. In such cases, it is possible only to ensure that all operations are carried out as carefully as possible.

Handling Pollen

Male flower collection

When the inflorescence opens naturally most of the many male flowers are not mature. Each day, over a period of two to three weeks, some open, shed pollen and fall off. One or two weeks after the inflorescence opens, when about a quarter of the male flowers have fallen, most of the remaining male flowers are sufficiently mature to give viable pollen. The branchlets carrying the male flowers are cut off, and the flowers stripped from the stalks. If the palm is not being used for policaps hybridization, there is no need to remove all the male flowers, and fruitset on these nonisolated, partially emasculated bunches is not reduced and may be enhanced.

For policaps hybridization, palms may be treated individually, in which case the male flowers from one inflorescence are put into individual labelled bags. For mascopol hybridization, male flowers from selected individuals of any one cultivar are bulked.

Flower drying

Pollen is readily released by drying the male flowers, which may be left on a bench at room temperature for some days, put in an oven or a specially constructed drying room at 40° C for 24–40 hours, or in a fluid-bed dryer at 40–60° C for three or four hours. The method chosen will depend upon the facilities available and the location of the pollen parents in relation to the place the flowers are to be processed or to where the pollen is to be used. It is essential to keep a flow of dry air passing over or through a thin layer of flowers. The flowers may be given an initial cracking to expose the drop of nectar secreted at the base of the anthers and are then dried for the appropriate period. After drying, they are sieved, cracked a second time, and sieved again. This method will get an amount of pollen equivalent to 1.5 to 2.5% of the fresh weight of the flowers with a viability of around 40%.

Pollen Storage

Once collected, pollen can either be used immediately or stored in a closed container for a few weeks in a refrigerator or a few months in a deep freeze. Longer-term storage at room temperature following vacuum freeze-drying is also possible.

Pollen Viability

Whether or not pollen has been stored, it is wise to test its viability before use. This can be done by preparing a culture medium composed of sugar, unflavored gelatin and distilled water (in the proportions by weight 2:7:20) mixed in a container which in turn is put in a pan of boiling water to dissolve the gelatin. The thinnest possible layer of jelly is poured, while still hot, into clean petri dishes, which are immediately covered to retain the condensation. When the jelly is cool, pollen is lightly dusted on it from a small brush and the lid replaced. After incubation for 1–5 hours at 30° C, germination can be observed under a low-power microscope. Pollen which germinates poorly is discarded. This technique is simple to follow and satisfactory for routine pollination work. It can be refined, and accurate counts may be made if desired. Sterility of glassware etc., as

in a pathology laboratory, is of minor importance since pollen will naturally carry spores of saprophytic fungi that will contaminate the whole germination medium if, for instance, it is left overnight. Sometimes poor viability is due to the loss of humidity above the pollen or to contamination of the glassware by detergent.

The biggest contamination risk in all work with pollen is from other pollen and it is essential to avoid mixing different lots. Care must be taken to label the flower bags and the pollen containers. Only one lot of pollen should be opened for use at any one time, and the cleaning of hands, arms, equipment, and surfaces with 70% alcohol between dealing with different lots of pollen is essential.

Attention

Neither the policaps nor the mascopol systems can eliminate operator error. Should there be any doubt about the parent palms used, the pollen collected, the efficiency of emasculation or pollination, or the legitimacy of the subsequent palms produced, the only safe procedure is to abandon the doubtful material.

Acknowledgments

This practical guide to coconut hybridization draws freely on the publications of other coconut breeders whose work is gratefully acknowledged. The specific information about the policaps and mascopol systems is published by permission of the Coconut Industry Board, Jamaica.