RAFI COMMUNIQUE

RURAL ADVANCEMENT FUND INTERNATIONAL

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COFFEE AND BIOTECHNOLOGY

ISSUE: The application of biotechnologies to coffea.
IMPACT: Coffee is now a smallholder crop in most areas of the world. Biotechnologies will facilitate shift to large-scale production which will become concentrated in fewer countries.
COUNTRIES AFFECTED: All coffee producers; most adversely affected will be the small, robusta-producing countries.
PARTICIPANTS: The world's two largest buyers and sellers of coffee: General Foods (subsidiary of Philip Morris) and Nestlé; as well as small biotech companies in the U.S., Singapore, and Japan (see company profiles).
ECONOMIC STAKES: Coffee is the Third World's most important agricultural export, worth (US) $10 billion a year to over 50 coffee exporting countries.

Introduction to Coffee

Coffee is the Third World's most valuable agricultural export commodity, followed by sugar, rubber and cacao. Worth approximately $10 billion annually to more than 50 nations of Latin America, Africa and Asia, coffee ranks second only to oil as a commodity export earner. For most coffee exporting countries, coffee is the major export earner.

With the exception of Brazil, Colombia, Kenya and Indonesia, coffee is not generally a plantation or estate crop. In most areas of the world coffee is grown by small farmers on diversified landholdings.

Brazil and Colombia dominate the world coffee market, accounting for 34 percent of world coffee exports in 1988, and 40 percent of total world production. Even so, coffee exports are vitally important to many countries throughout Africa, Asia and Latin America. In Rwanda, for example, approximately 500,000 farmers grow coffee on tiny plots averaging only one-tenth of a hectare (1 hectare = 2.471 acres). In Indonesia, 650,000 farmers grow coffee on plots averaging one hectare in size. In Colombia, there are approximately 300,000 coffee farms averaging 3.4 hectares in size. It is no exaggeration to say that millions of peasant farmers worldwide depend on coffee

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cultivation for some portion of their livelihoods.[1]

Given the importance of coffee to Third World producers, it is vitally important that these countries are fully informed about the potential applications of biotechnologies to coffee, and the implications for the future of coffee growers/economies of the Third World.

Origins of Coffee

The are more than 100 species of coffea, but only two are widely grown commercially. Both are native to Africa. The primary centre of diversity of *Coffea arabica*, the most commercially important species, is Ethiopia. *C. arabica* represents 70% of the commercial coffee of the world, and about 99% of the Latin American production. *C. arabica* is cultivated at higher altitudes, and is generally regarded as the highest quality coffee beverage.

The centres of diversity for *Coffea canephora* (commonly called "robusta" coffee) are mainly in central and western equatorial Africa and in Madagascar. *C. canephora* is grown in tropical areas at lower altitudes; 80 percent of Africa's coffee production is from this species.

Like many other tropical export commodities, the history of coffee cultivation since the colonial era is one of extreme genetic uniformity. In 1706, a single arabica coffee plant from Java survived the long journey to Amsterdam's botanical garden. Coffee plants later introduced throughout the New World descended from this one plant. Today, coffee plants throughout the Americas are plagued by several devastating diseases, especially *Hemileia vastatrix* (coffee leaf rust) and *Colletotrichum coffeanum* (coffee berry disease).

Coffee rust, a fungus that attacks the leaves of coffee plants, is "universally regarded as one of the greatest plant plagues of all time."[2] In the 1860s, leaf rust decimated Ceylon's coffee economy, and ended arabica coffee cultivation throughout much of Asia. Latin America remained free of coffee leaf rust until 1970, when it was discovered in Brazil.

Coffee rust continues to be a serious threat to arabica coffee producing nations, but it can be controlled with expensive and frequent spraying of copper-based fungicides. In 1983, for example, the control of leaf rust using fungicides cost more than $100 per acre in Mexico. The cost of treating Mexican coffee plantations was estimated to be $66 million a year, roughly one-eighth of the country's coffee export revenues.[3] As of November, 1987, 70 percent (over 700,000 hectares) of Colombia's coffee was infected with rust. The cost of controlling leaf rust in Colombia has increased production expenses by up to 20%.[4] Though coffee rust can be controlled, the use of fungicides is too expensive for general use by most small coffee growers.

International Coffee Trade

Since the early 1960s, worldwide trade in coffee has been regulated by the International Coffee Agreement (ICA), which is administered by the International Coffee Organization (ICO) based in London. Virtually all of the world's coffee exporting countries (50 members accounting for 99% of all production) and importing countries (24 members accounting for 90% of consumption) are members of the ICO. The ICA attempts to balance supply and demand by regulating coffee production under a system of export quotas, and by establishing fair prices for both producers and consumers.

The interests of the largest coffee producing nations (especially Brazil) clearly dominate coffee negotiations. But the ICA's system of quotas and support prices has traditionally guaranteed some level of stability for the small, robusta producing nations of Africa. With ever-increasing demand for the milder, higher quality arabica coffee, however, robusta producers are losing ground on world markets.[5] Major coffee importers, along with dominant coffee producers (especially Brazil and Colombia), are demanding adjustments in the ICA which will give arabica producers more flexibility and market share--at the expense of the robusta producers. Since so many of Africa's robusta-producing nations depend on coffee as a principal export earner, further loss of export markets and drop in prices could be devastating.

The crowning blow came in early July, when the International Coffee Agreement collapsed and export quotas were suspended.[6] Brazil immediately lowered its export price by five percent. Within one week, New York coffee futures prices plunged 18%. If the free market prevails and a new ICA is not negotiated, trade analysts predict that many small coffee producing nations will be forced out of production, leaving only the largest producers (Brazil, Colombia, Mexico, Kenya and Indonesia).[7] They predict that Brazil could capture 50% of worldwide exports next year (increasing its share from the current 30%).[8]

Whatever the outcome, the future looks grim for the smaller robusta-producing nations (especially, Angola, Madagascar, Congo, Philippines, Benin, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Togo, Uganda, Zaire).[9]

Coffee and Biotechnology--Work in Progress

Coffee is a perennial tree crop which has proven difficult to improve through traditional breeding, largely because of sexual incompatability between commercial species and the excessive amount of time needed for breeding generations of coffee plants. The release of a new coffee variety using conventional breeding requires 15-20 years.

Recent advances in biotechnology, however, offer many possibilities for altering specific agronomic, processing and consumer qualities of the coffee plant and coffee beverage. In fact, scientists consider <u>coffea</u> "an ideal <u>in</u> <u>vitro</u> model system for improvement via tissue culture as well as genetic transformation."[10] The following is a brief introduction and review of work in progress on coffee and biotechnology. (For more information about specific companies, see "Company Profiles" on page 9-10.)

<u>Tissue Culture Technologies</u> -- Various tissue culture techniques are being applied to <u>coffea</u> which can drastically accelerate breeding programs and release of new coffee varieties.[11] Micropropagation is being routinely used to mass produce new, genetically uniform coffee plants for large-scale plantings. The technique involves propagation of new plantlets from buds or tissues which have the capacity for rapid cell division. It would normally take scientists 35 years to obtain a rust-resistant coffee hybrid. Using <u>in</u> <u>vitro</u> tissue culture techniques, however, scientists have already developed a rust-resistant hybrid between the two species of arabica and robusta. The resulting hybrid, arabusta, cannot be reproduced by seed, but micropropagation enables the mass production of 20,000 plantlets from a single cutting in 12-18 months.[12]

In Singapore, Plantek International (a biotech company owned by U.S. and Japanese interests) is cloning a new, rust-resistant arabica coffee variety for large-scale planting in Southeast Asia. Prior to the development of Plantek's new rust-resistant variety, the threat of coffee rust had virtually elminated arabica coffee production in this region of the world. Plantek's new coffee clones may signal the rise of Southeast Asia as a major coffee-growing region in the future. The government of Brazil, through its EMBRAPA agency, is also using micropropagation to mass produce new coffee clones.

Other tissue culture techniques (somaclonal variation and somatic embryogenesis) offer means of inducing mutations in plant segments, and thus provide starting material for new coffee breeding programs. These techniques are used to identify and then exploit new characteristics which result from induced mutations.

DNA Plant Technology, Inc. (USA), under contract with General Foods (USA), focuses on the use of somaclonal variation for the discovery of new, desirable traits in coffee improvements. Using this technique, new plants can be released within half the time required by conventional breeding.[13] Somaclones developed in DNAP's laboratory were planted in Brazil three years ago, and have yielded their first crop.[14]

Research on somatic embryogenesis (plant embryos encased in nutritive pellets which germinate like seeds) will someday result in the production of artificial coffee seeds.[15] Since somatic embryos can be reproduced faster and in much greater quantities than plants produced via micropropagation, this technique will profoundly affect the availability and distribution of new, genetically altered coffee plants in the future. Synthetic hybrid seeds would facilitate the growth of large-scale coffee plantations because they would afford greater productivity and uniformity.[16]

Cell Fusion -- One important technique for genetic manipulation of coffea is protoplast fusion. This technique involves the use of special enzymes to dissolve the walls surrounding plant cells. The wall-less cells are called protoplasts. By fusing two cells together, their genetic material is combined to form a single, hybrid cell. If the protoplast can then be regenerated into a plant, the result is a new, transgenic plant. In 1987, scientists suceeded for the first time in regenerating coffee plants from protoplasts.[17] Protoplast fusion is a technique for introducing large numbers of genes, and since most important traits are controlled by multiple gene functions, protoplast fusion offers great potential for the future genetic manipulation of coffea.

Molecular Genetics -- More precise, sophisticated techniques for genetic engineering of coffea are also on the horizon, although little information is available about specific research programs. Escagenetics, a small biotechnology company based in San Carlos, California (USA), claims to be the first company to develop the genetic engineering technology to manipulate the characteristics of coffee, and is now in the process of acquiring patent protection for these developments. Despite these claims, other scientists believe that practical results from gene transfer or recombinations may still be 10-20 years in the future.

Specific Research Goals--Biotechnology and Coffee

The application of biotechnologies to coffea can be applied at different levels of complexity. It should be stressed that most are in the early stages of development, and some may not be realized until early in the next century. Even so, the potential is enormous.

Based on a review of literature on coffee and biotechnology, the following is a list of current and future research goals for the genetic manipulation of coffea plants:[18]

--breeding for disease resistance, especially rust-resistant varieties
--developing caffeine-free coffee varieties, or beans with lower caffeine content

--development of trees with uniform flowering and longer retention of ripe fruit to facilitate mechanical harvesting
--insect resistance as a means of cutting production costs and lowering pesticide residues in coffee beans
--developing coffea plants with herbicide tolerance
--modification of seed proteins--altering chemical composition of the beans and increasing solids content to increase yields
--frost toleance

What Impact on Coffee Growers?

Although most work on coffee and biotechnology is in the very early stages, it is not difficult to speculate on the consequences for coffee producers of the Third World.

Genetic Uniformity: Micropropagation techniques and mass propagation of new coffee clones will likely intensify genetic uniformity in commercial coffee production. If widely introduced on large-scale plantations, even the new, disease-resistant varieties may prove highly susceptible to disease and pests.

Overproduction and Lower Prices: Mass propagation of coffee plants may also facilitate the growth of large-scale coffee plantations or estates, undoubtedly leading to overproduction and a subsequent drop in coffee prices. As with most major commodities, it is usually the largest coffee producers who can afford to adopt new coffee varieties, and they will be the most likely to survive a restructuring in the coffee economy following a decrease in commodity prices.

Increase in Purchased Inputs & Decrease in Labor Needs: If successful, attempts to develop trees with uniform flowering and longer retention of ripe fruit will facilitate the introduction of mechanically harvested coffee. Labor-saving characteristics are clearly aimed at large-scale coffee producers. Mechanical harvesting of genetically uniform coffee trees would undoubtedly reduce the need for harvest labor and small-scale coffee growers.

Similarly, the goal of producing herbicide tolerant coffee varieties would increase the use of purchased inputs and decrease the need for labor. The increased use of herbicides would threaten the safety of agricultural workers and compound environmental problems associated with chemical pollution.

Transfer of Production: Coffea is extremely susceptible to frost, a factor which has devastated many valuable coffee crops, most notably in Brazil. If scientists succeed in developing frost tolerant coffea, it could help coffee growers in areas which are especially threatened by frost. But it could also have a dramatic impact on where coffee is cultivated--possibly even extending cultivation to temperate climates.

The goal of developing coffee varieties with lower caffeine content would undoubtedly result in a substantial savings for major coffee processors who now use a chemical process for de-caffeination of beans.

Multiple Sourcing: Modification of seed proteins or genetic alterations in the chemical composition of the coffee bean, could bring about the most far-reaching impacts on future coffee production. If scientists succeed in altering chemical composition of the coffee bean, it may be possible to "custom design" desired coffee bean flavors and quality without limits imposed by the standard coffee varieties and their traditional agronomic characteristics. According to PA Technology Ltd.:

> "...a research programme could isolate the gene coding for an arabica seed protein, introduce it into the genetic information of robusta plants and test for effects on "cup quality." Conversely, a robusta seed protein could be introduced into arabica varieties. Seed proteins from species other than coffee could be introduced, to assess their impact on "cup quality". For example, the brazil nut protein is rich in sulphur--containing amino acids, and its introduction into coffee would provide insight on the role of sulphur-containing constituents in flavour development."[19]

Even more fantastic is the future possibility of harvesting coffee from common bean varieties that have been genetically altered to synthesize coffee flavor. In a 1987 article appearing in Tea & Coffee Trade Journal, Dr. Samuel Lee explains:

> "Insert the coffee DNA nucleus into more common and more easily grown and harvested varieties--lentils, kidney beans, garbanzos, limas, or even peanuts. Coffee genes could be implanted with emphasis on various flavors, higher, lower or no caffeine, high solubles or several combinations of these factors. This could lead to the growth of high quality coffee in almost any climate and in almost any country in the world."[20] (emphasis added)

Conclusion--The Winners & The Losers:

Today, coffee is predominantly a smallholder crop. The applications of biotechnologies to coffea in the next few decades will facilitate a fundamental shift to large-scale coffee growing estates/plantations. The largest Latin American coffee producing nations (particularly Brazil) will continue to dominate. Southeast Asia may, once again, become a major arabica coffee-growing region. The small, robusta-producing nations (principally African), where coffee is grown predominantly by peasant farmers, will suffer the greatest losses. Since many of these countries depend on coffee as the principal export commodity, the economic impact could be especially devastating.

New biotechnologies have the potential to transform dramatically the agronomic and processing qualities of coffea. The highly concentrated coffee industry of the North, controlled by a handful of giant, transnational food corporations, will reap the greatest benefits of these new technologies. The inevitable "losers" will be millions of small-scale coffee growers throughout the Third World.

Recommendation to the International Coffee Organization

One of the objectives of the ICA is "to foster economic diversification and development of coffee producing countries." RAFI believes that the ICO has an important role to play in making member countries aware of the potential negative impacts of the applications of biotechnology to coffea. The ICO has already funded a major report on biotechnology and coffee, but it did not include an analysis of the social and economic impacts.

We recommend that the ICO carefully monitor public and private biotech research on coffee, conduct a thorough analysis of the socio-economic impacts, and establish an "early warning system" to alert member countries to the need for immediate planning and diversification.

Company Profiles
Current Research on Coffee and Biotechnology

[Most research on coffee and biotechnology is being conducted by private enterprise, and is proprietary. Company officials are willing to share only general information about their research, goals and objectives. The following information is gleaned from personal interviews with company officials, annual reports and published information.]

DNA Plant Technology Corp. (New Jersey, USA) is a leading agricultural biotechnology firm specializing in tissue and cell culture technology for crop improvement and food products. Under an agreement with General Foods Corp. (see below), DNA Plant Technology is using somaclonal variation to develop new coffee varieties. Their goal is to "develop coffee varieties with new consumer or processor benefits" and to increase coffee consumption by improving the quality of the beverage. The company is seeking to improve agronomic properties of arabica coffee such as bean flavor, yields, growth cycle, etc. New varieties developed in DNAP's laboratory are being field tested in Brazil and have yielded their first crop. The company will not release information about results.

General Foods (New York, USA) Kraft General Foods Group (KGF) is the $22.5 billion subsidiary of tobacco-food conglomerate Philip Morris (USA), and the second largest food company worldwide, behind Nestle (Business Week, May 8, 1989, p.74.) In the USA, KGF sells 14 of the top 50 U.S. food brands. General Foods accounts for one-third of the U.S. coffee market. Contract with DNA Plant Technology Corp. for coffee improvement (see above).

Escagenetics (California, USA) is a small biotechnology company specializing in plant biotechnology for food products and agriculture. The company is best known for its work in bio-synthesis of vanilla. Research on coffee is proprietary, without a corporate sponsor. According to Escagenetics' vice-president for research and development, the company is "a dominant player" in coffee biotechnology, and has a significant program to genetically transform properties of coffee to improve consumer traits. Research efforts are focusing on two areas: developing coffee plants with superior agronomic qualities and developing coffee with "desirable attributes", including reduced caffeine content and increased extractable solids. The company has been working on coffee since 1985, and claims to be the first "to develop the genetic engineering technology to manipulate the characteristics of coffee." The company is "aggressively pursuing appropriate patent coverage" for this work.

Nestlé (Switzerland) is the world's largest food company with

1988 annual sales of approximately (US) $24 billion. Nestlé is probably the world's largest buyer and seller of coffee. Virtually no information is available about the company's research on coffee and biotechnology, though Nestlé conducts field work on coffee plantlets in the Philippine province of Bukidnon and established a biotechnology center near Lausanne, Switzerland in 1987.

Plantek International Ltd. (Singapore) was formed in 1984 as a joint venture between **NPI** (Native Plant Inc., Utah, USA), **Tata Enterprises** (India), **Sumitomo Chemical Co., Ltd.** (Osaka, Japan), and **Kyowa Hakko Kogyo Co., Ltd.** (Tokyo, Japan). Plantek's mission is "to actively develop and promote improved varieties of plantation crops and plants of high commercial value in Southeast Asia, the Indian subcontinent, and East Africa."

In 1985, Plantek announced the development of a new rust-resistant coffee plant with "full rich flavor." The company became the first to tissue culture successfully the new coffee hybrid, and is commercially producing thousands of new coffee plants (World Coffee and Tea, September, 1985, p. 45). The company has developed elite varieties of coffee and testing is underway in Japan to measure taste characteristics of Plantek's cloned coffee trees (NPI Annual Report, 1988, International Operations). Plantek's coffee clones are being introduced throughout Southeast Asia.

[1] Statistics on size and number of coffee farms comes from: de Graaff, J., The Economics of Coffee, Pudoc Wageningen, 1986, p. 76.

[2] Anonymous, USDA Foreign Agricultural Service, memo from Rio de Janeiro, Brazil to Washington. Undated, # BZ-0032, written at the time coffee rust was first discovered in Brazil.

[3] Sasson, Albert, Biotechnologies & Development (UNESCO, Paris, 1988) p. 38.

[4] Personal communication with Dr. Maro Sondahl, DNA Plant Technology, Inc.

[5] Stainer, Robin, "A Giant Under Seige", South Magazine, December, 1988, p. 105.

[6] Quotas have been abandoned twice before, but this is the first time quotas have been abandoned on a falling market.

[7] Blackwell, David. "Coffee Producers Could be Forced Out of Business", Financial Times of London, July 13, 1989, p. p.38.

[8] Ibid.

[9] Cote d'Ivoire is the largest robusta producer. Other ICO members exempt from basic quota include: Ghana, Guinea, Liberia, Nigeria, Sierra Leone, Sri Lanka, Thailand, Trinidad & Tobago.

[10] Sondahl, M.R. and Loh, W.H.T., "Coffee Biotechnology" in Coffee, Ed. by R.J. Clarka and R. Macrae, Elsevier, 1987, p. 236.

[11] It should be noted that tissue culture techniques can also be employed to facilitate germplasm exchange and conservation of endangered native land races.

[12] Sasson, Albert, Biotechnologies and Development (UNESCO, Paris, 1988) p. 39.

[13] Sondahl and Loh, op. cit., p. 239.

[14] DNA Plant Technology, "Tropical Plant Products", 1988 Annual Report, p. 9.

[15] Institut de recherches du cafe et du cacao (IRCC) Cafe, Cacao, Te "Summary Report", Association scientifique internationale du cafe (ASIC) No. 3, July-Sept., 1987, p. 223

[16] Sondahl, M.R. and Loh, W.H.T, "Coffee Biotechnology" in Coffee, ed. by R.J. Clarke and R. Macrae, Elsevier, 1987, p. 256.

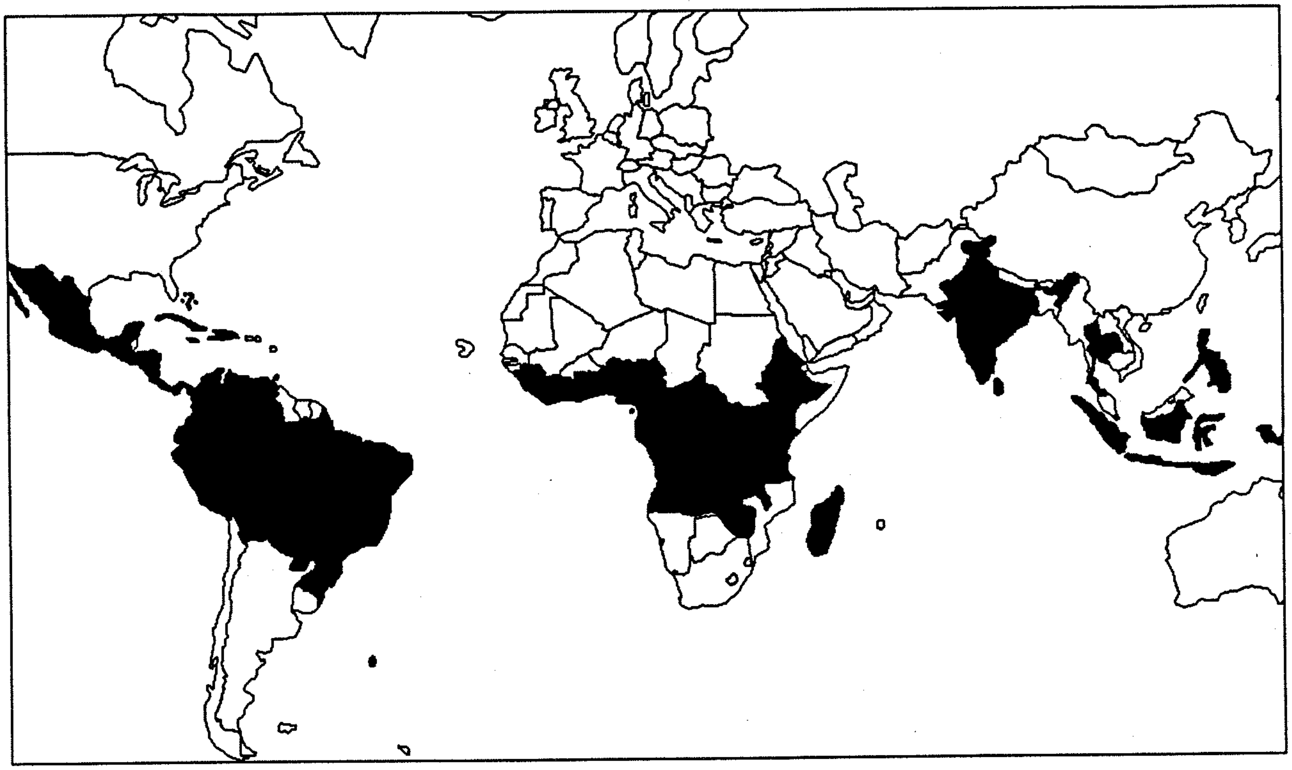
[17] Sasson, op. cit., p. 40.

[18] Sources include, especially, Coffee and Biotechnology: A Summary of the State of the Art, prepared for the Intl. Coffee Organization by PA Technology Limited, UK, 1986.

[19] PA Technology Ltd., Coffee and Biotechnology, p. 18.

[20] Lee, Samuel, "Synthetic Coffee May Well Come on the Market in the Near Future", Tea & Coffee Trade Journal, August, 1987, p. 5-6.

COFFEE EXPORTING NATIONS
Worth $10 Billion Annually to 50 Third World Producers



Source: RAFI

Coffee's Share of Total Exports (Selected Countries)
1982-1984

<u>Latin America</u>

Colombia--50%
Costa Rica--26%
El Salvador--59%
Guatemala--31%
Haiti--27%
Honduras--22%
Nicaragua--27%

<u>Africa</u>

Burundi--87%
Cameroon--20%
Central African Rep.--32%
Ethiopia--62%
Ivory Coast--19%
Kenya--26%
Madagascar--37%
Rwanda--68%
Tanzania--35%
Uganda--93%

Source: IBRD, Commodity, Trade and Price Trends, 1987-88 Edition (Baltimore: The John Hopkins Univ. Press for the World Bank, 1988), pp. 20-24.