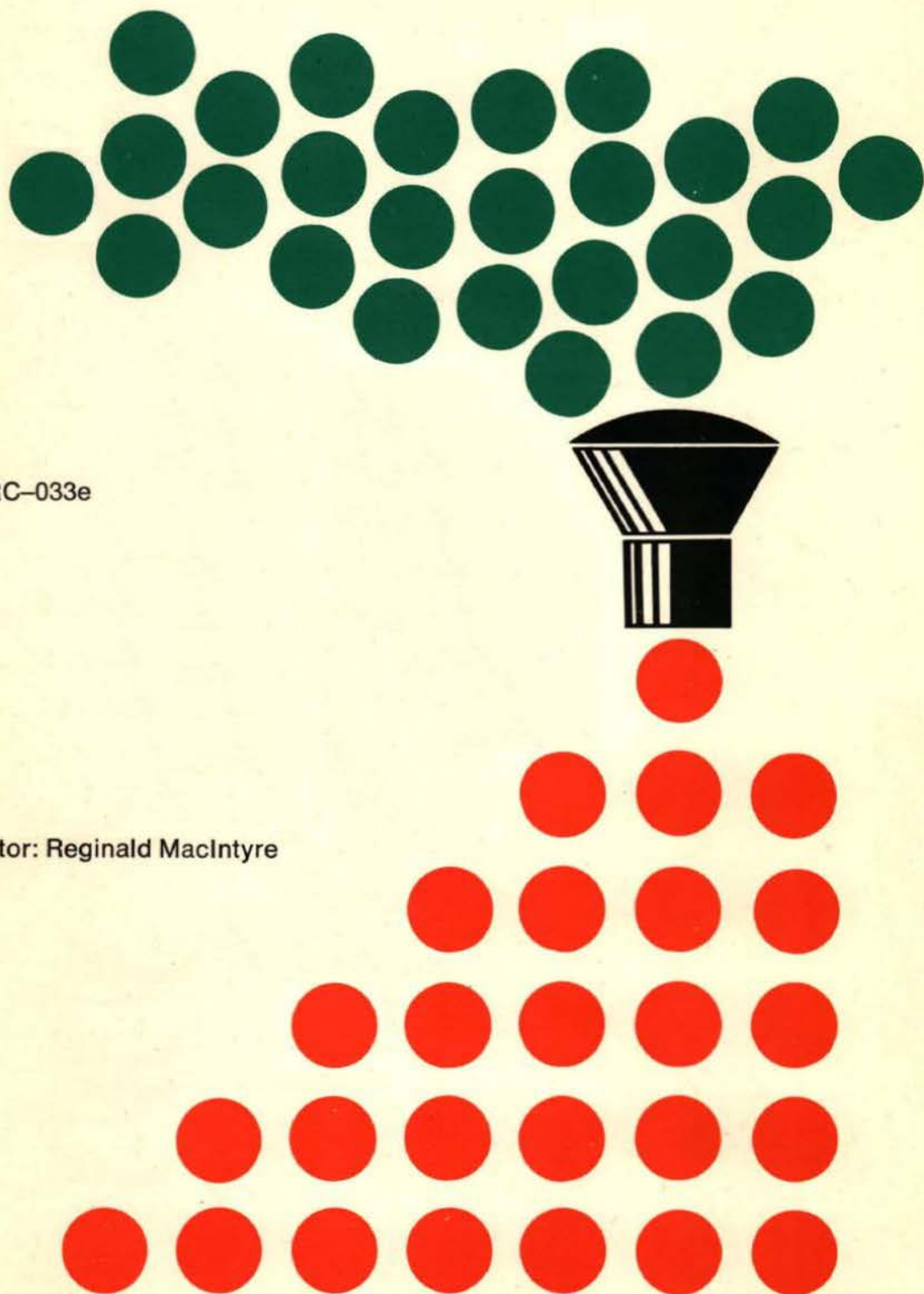


Interaction of Agriculture with Food Science

Proceedings of an interdisciplinary symposium
Singapore, 22-24 February 1974

IDRC-033e

Editor: Reginald MacIntyre



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Foreword

To offer you, the reader, advice before you study this book is at best a mild impertinence and at worst an insult to your judgment. I risk these charges because, before you read, I wish to draw your attention to an aspect which you might otherwise miss.

This book is by Asians for Asians and deals with Asian agricultural and food problems. Two of the contributions are from non-Asian countries but they are from countries with closely related food needs. As the experience of the past quarter century shows, the problems of the developing world will only be solved by those who live there. However well-intentioned, foreign advisers inevitably tend to see solutions to problems in terms of their own cultures and technological traditions. The material resources to make the symposium possible stemmed from the International Development Research Centre. The International Union of Food Science and Technology accommodated the symposium within the framework of its normal scientific activities, but neither of the sponsoring organizations wished to present the participants with ready-made solutions imported from areas of material prosperity.

So new ground is broken in a debate unsullied by the "You can have my aid if you do things my way" approach. The questions raised in this meeting, the conclusions reached, and the recommendations made were drafted by the men on the spot, holding day-to-day responsibility for the welfare of their own peoples. You, the reader, will judge the quality of their work and the honesty of its purpose. This book deals with root-stock reality even if it raises more problems than it solves.

JOHN HAWTHORN
Vice-President IUFoST



Introduction

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Program Director

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Mahatma Gandhi writing in "Young India" in 1921 said: "To a people famishing and idle the only form in which God dare appear is as work and as a promise of food as wages."

To many millions among the poor rural communities of Asia, Africa and Latin America, food in the form of the subsistence crops they raise represents literally the only wages they ever receive in return for their exceedingly arduous labours. To most people in the affluent nations the balance between population and food production is a matter of comparative statistics; to the Asian farmer it is a matter of survival.

It is estimated that in 1974 the total world population is of the order of 3.9 billion. During the 25 years to the end of the century, it is probable that this number will increase to nearly 7 billion. By far the greatest increase will likely take place among the developing nations, who at present represent two thirds but by 2000 AD will comprise close to three quarters of the world's population. The authors of the UN Food and Agriculture Organization's Indicative World Plan, published in 1969, suggested that in order to satisfy population and other demand pressures, the production of cereal grains and other food crops would need to increase by no less than 4% per annum. At its 59th meeting in December 1972, the Council of FAO expressed "grave concern" over the trend in agricultural production which showed a global increase of only 1-2% per annum.

During most of the past 25 years, whenever serious shortfalls in food grain production occurred in the low-income countries, the caloric imbalances were to some extent alleviated by imports of grains from surplus producers such as the USA, Canada and Australia. Much of this imported grain was at least partially financed through international assistance programs. This picture is rapidly changing to the disadvantage of the poorer nations. During the past 10 years the consumption

of animal products has risen rapidly among the more affluent nations. Since the early 1960s, in North America, meat consumption has increased by roughly 2.2%, in Western Europe by 3%, and among the Eastern European nations including the USSR by 3.7% per annum. In India, where most of the grains produced are eaten directly as human food, annual average grain consumption is equivalent to about 177 kg per capita. In North America, where most of the grain is first converted to meat and other animal products such as milk, butter and eggs, the annual per capita consumption averages more than 900 kg. The rapidly increasing demand for animal feedstuffs by North Americans, East and West Europeans and Japanese, has severely restricted the quantity and dramatically raised the price of edible grains available for export from the surplus to the chronically or occasionally deficient producers of the developing world. Consequently, Asians, Africans and Latin Americans may well look in vain to the traditional exporters for grains in the quantities they need and at prices they can afford to supplement their indigenous production. In summary, the least affluent nations must of necessity become much more self-sufficient in food grain production.

A great deal of progress has become apparent in recent years in improving agricultural technologies and the yield capability of the traditional subsistence grains, wheat, rice, and maize. The splendid work of the research scientists at the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines has justifiably earned them world-wide acclaim.

A new international agricultural research centre has been established at Hyderabad in India, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). As the name suggests, its concern is with the crops of the dry regions of the world, including the cereals, sorghums and millets. Many millions throughout Asia and Africa look hopefully to the scientists at ICRISAT to bring forth increases comparable to those to which the research at CIMMYT and IRRI has given rise.

The advent and introduction of the high-yielding varieties of wheat and rice gave cause for cautious optimism that given reasonably favourable climatic conditions, the total production of cereal grains in the developing countries could be greatly increased. The tragic events which occurred in 1973 in West Africa and parts of Asia served to emphasize how tenuous is the present balance between human need and the availability of the major subsistence crops. A factor which is seriously compounding the difficulties of the poor nations of Asia and Africa is a direct result of the dramatic recent increase in the cost of petroleum products. The principal source of fertilizer nitrogen is naphtha gas, a petroleum refinery by-product. In order to realize their fullest productive potential, the "high-yielding" cereal varieties are heavily dependent upon nitrogenous fertilizers. The new wheat and rice varieties which between 1968 and 1972 raised cereal production on India's irrigated farm land by more than 20% demonstrated a marked responsiveness to inputs of nitrogen. The consumption of nitrogen dur-

ing the period under discussion rose nearly four-fold from one half to nearly 2 million tons/year. During the past year, the price of nitrogen, as urea, has risen from a little over 15¢ us to nearly 35¢/kilo. There are some reports to suggest that several Asian nations have paid as much as 55¢/kilo for deliveries of urea from Eastern Europe.

The net result is that as exciting new agricultural technologies are offered to Asian farmers with a promise of dramatic increases in cereal grain yields, the cost of implementing these technologies is escalating at an alarming rate. The poor peoples of the least developed nations are thus confronted with formidably high prices in the future for food grains, whether they opt for attempted self-sufficiency in agricultural production or choose to supplement their national production with imports from the surplus producers of cereal grains.

It is not surprising that one of the recommendations of this Symposium was that greater attention be given to research into cropping systems, such as those which combine the production of cereal grains and food legumes, which make for a more efficient use of soil nitrogen.

There can be little doubt that efforts to increase the efficiency of production of the major subsistence crops must be expanded with vigor and imagination, both within the international agricultural research centres (IARCS) and through the expansion and strengthening of national agricultural programs. But improved agricultural technologies are only one component, albeit a most important component, of the total food production and delivery system. There is little purpose in increasing grain production in order to increase the caloric intake of rodents, insects and microorganisms. I recall several years ago the somewhat cynical comment of a senior official of an agriculture department in a developing country: "It is cheaper to grow another ton of grain than to build stores to protect a ton of grain." If this were ever true, which I strongly doubt, it can never be true within the foreseeable future. Freedom from hunger in Asia, Africa and Latin America will become more and more dependent upon *freedom from waste*.

Until the time of this Symposium, scant research attention had been devoted to post-harvest systems as compared with production techniques. One of the most telling observations of the Symposium appears among the "Questions, Conclusions and Recommendations": "It was suggested (by the Symposium) that post-harvest scientists, including food scientists and technologists and agricultural engineers, have a less clearly defined set of objectives than the plant breeders and agronomists."

One can find very few examples of a concerted research effort which comprehended the total system, from the time of and including harvesting through all the intermediate activities and processes, until the grain was delivered as food into the mouths of the consumers. The tendency appears to have been to demonstrate the components of the post-harvest system as single, isolated activities.

In more than a few instances the emphasis has been placed upon adapting machines and techniques developed for a system far removed in scope and style from the needs of Asian rural communities. This point is well illustrated in Dr de Padua's paper "Post-harvest protection

and processing of rice.” One of the Symposium participants referred with feeling to the many “foreign experts” who arrive in Asia with a solution seeking a problem. The “transfer of technology” is not simply a matter of translocating a complete mechanical system from Minneapolis, Montreal, Manchester or Marseilles to a village in Malaysia or Madya Pradesh. Rather it is the transplanting of sound scientific principles for the design and development of machines and mechanisms relevant and appropriate to the total system which exists or is being established. Science is in large measure transmittable between different economies and cultures; technology in many instances is not.

While calling for greater attention within Asia to post-harvest research, including the problems of harvesting, threshing, drying, storage, processing, distribution, marketing and utilization, the participants strongly urged a closer integration of activities between the plant scientists dedicated to the improvement of crop characteristics and cropping methods, and those devoted to post-harvest protection, processing and distribution. The participants specifically urged that two of the international agricultural research centres located in Asia, IRRI and ICRISAT, expand their programs to include research into the post-harvest problems related to the crops of their particular concern. If either or both of the two IARCs find themselves unable to include adequate programs of post-harvest research, the Symposium strongly recommended that existing institutions be strengthened, or that new post-harvest research organizations be created in close proximity to these IARCs to encourage a close integration and coordination of research effort embracing the whole pre- and post-harvest systems.

The Symposium was unique in several aspects. It was the first Symposium sponsored by the International Union of Food Science and Technology to be held outside Europe or North America; the first in which all of the papers were presented by scholars and scientists from developing countries (in this case all but two were Asians); the first in which agricultural, food and social scientists addressed themselves collectively to the food problems of a major continent.

The Symposium consisted of four sessions. At the first, two internationally renowned economists reviewed the Asian food and agricultural scene in broad perspective. The second session was devoted to crop improvement research and four speakers, one from IRRI, one from ICRISAT, one from the West Indies and one from the University of the Philippines, reviewed, respectively, research on rice, the crops of the semi-arid tropics, the important root crops of Asia, and the means to increase farm productivity through multiple-cropping systems.

The subject of the third session was quality control, post-harvest protection and processing. The first speaker, from the International Maize and Wheat Improvement Centre (CIMMYT), described the essential support which the food scientist and food analyst must provide to the plant breeder. The second paper presented a comprehensive review of the total post-harvest system as it concerns rice in Southeast Asia. The third and fourth speakers described the technologies and economics related to the processing of cassava and food legumes, respectively.

The last session was concerned with food processing industries. The first speaker was the Director-General of a national paddy and rice authority. The second was the Managing Director of probably the most successful dairy cooperative in Asia. The third and final speaker was the Chairman of the Singapore Institute of Standards and Industrial Research (SISIR).

The last day was dedicated entirely to a discussion and the formulation of a set of questions, conclusions and recommendations. The Symposium appointed a drafting committee under the Chairmanship of Dr Encik Anuwar bin Mahmud, the Director of the Malaysian Agricultural Research and Development Institute. The Questions, Conclusions and Recommendations prepared by the drafting committee and approved by the participants in the Symposium appear immediately following this Introduction.

The Recommendations are preceded by a number of important questions which were raised by the participants. A number of these questions have been dealt with in the Recommendations. Several others, including those which concern national food and agricultural policies and the policies of the IARCS, are entered into the record in the hope that those whose business it is will give them serious and thoughtful consideration. Hopefully, there will be an opportunity for at least some of the group to meet again in order to discuss at greater length some of the questions posed but unanswered.

I feel sure that I speak for the non-Asians who were privileged to be present at the Symposium when I say that it was a most inspiring and encouraging experience. In spite of the many difficulties which confront the Asian nations, one can look with more than cautious optimism to the future of Asian food and agricultural research and development after being exposed to the manifest wisdom and understanding of the distinguished Asians who took part in the Symposium. One is impressed with the notion that in the past, scientists, aid administrators and politicians of the so-called developed nations and the international development agencies may have spent too much time in advising and too little time in listening to the scholars and scientists of the developing nations.

One can but hope that the initiative of the International Union of Food Science and Technology will encourage more of us to follow the advice of Horace and "listen all in silence" to our scientific colleagues in Asia, Africa and Latin America. We may very well be surprised how very much we shall learn.

Questions, Conclusions and Recommendations

Some Questions Raised by the Symposium

Many problems were presented and discussed including major socio-economic questions. However, only problems closely related to agriculture, food, and nutrition are included in the conclusions and recommendations.

To a large extent the Symposium was concerned with resources, both human and material. The major problems are: (a) how to achieve a more equitable distribution, and (b) a more efficient use of these resources.

A MORE EQUITABLE DISTRIBUTION

Should the primary emphasis in food and agricultural research be placed on the needs of the poorest people, the malnourished, and the least developed?

If the small farmer, the small processor, the low-income and under-employed are to receive our greatest attention, are the present systems and programs of food and agricultural research, development demonstration and training in Asia sufficiently well-oriented to the needs of these underprivileged people? If they are not, how can more suitable and effective programs of research and development be designed and implemented?

A MORE EFFICIENT USE OF RESOURCES

The material resources include: (a) land, (b) inputs such as irrigation devices and water, fertilizers, pesticides, machinery, and (c) outputs including crops and animals.

Representatives of the international agricultural research centres (IARCS) defined many of the specific objectives related to improved use of land and material inputs (e.g. better-yielding varieties, multiple-cropping systems, drought stress tolerance, pest resistance, efficient water and fertilizer utilization, better land management, and more efficient tools and equipment).

Some of the problems related to a more efficient use of outputs were defined: improved harvesting and post-harvest protection, processing, and distribution; cereals of higher nutritional value; better processing technologies.

However, it was suggested that post-harvest scientists, including food scientists and technologists and agricultural engineers, have a less clearly defined set of objectives than plant breeders and agronomists.

The IARCS (CIMMYT, IRRI, ICRISAT) have demonstrated what can be

achieved by large centralized, well-coordinated research programs when the primary objectives are clearly defined.

Is it possible to define equally precise and urgent research programs to attack harvest and post-harvest problems (threshing, drying, storage, processing, distribution, marketing, utilization, etc.)? Are such problems best tackled by massive, centralized regional research programs, or by a cooperative, integrated series of smaller programs in national institutes and universities?

Man is more capable of making technical progress than applying such progress for human benefit. We are better at controlling technical processes than human resources. If these statements are true, what can be done through research, training and demonstration to orient food and agricultural research to greater human benefit?

Are university and other advanced training courses in food and agriculture too technical? Would there be an improvement of university training in food and agriculture including also courses in practical economics, sociology, politics, and administration?

Alternatively, would the principles of resource management and practical human relations be better applied in the form of private initiative as in the case of milk and dairy cooperatives in India, or by universities already involved in such projects as the MaeKlong rural development project in Thailand and the multiple-cropping project in the Philippines and "Operation Flood" in India?

Should the programs of the IARCS be comprehensively vertically integrated to include crop and animal improvement and production (and other related disciplines)? Should they also carry out research into the major components of pre-harvest and post-harvest operations with emphasis on the total pre-harvest and post-harvest systems including drying and storage?

Should not socioeconomic aspects also be given consideration by the IARCS, working closely with national institutions?

If the IARCS undertake this large research package, what is to be the role of the universities and national institutions? Should they concentrate on adaptive research (using the results of the IARCS and adapting these results to local conditions) and carry out the demonstration and training programs necessary to bring technical improvement to the small farmer, processor, or distributor?

Can the larger universities and research institutions in Asia and in the developed world support the IARCS by carrying out fundamental research into specific problems such as in plant physiology and biochemistry, and in the development of rapid methods of analysis for screening of a large germ plasm collection?

Recommendations

1 The Symposium participants strongly emphasized the need for greater attention to the total system of harvest and post-harvest technologies in all the major crops of the Asian region. It was recommended that, as far as possible, the international agricultural research centres (IARCS) in the region (IRRI and ICRISAT) expand their programs to include research into the post-harvest problems related to the crops of

their particular concern. The scope of this post-harvest research should include the techniques of harvesting, threshing, drying, storage, and primary processing.

If the IARCS are unable to include adequate programs of post-harvest research, steps should be taken to strengthen existing organizations or institutes or establish new ones where necessary, to coordinate research programs for the whole region. For this purpose the identification of problems of high priority and suitable institutions and personnel in the region is of paramount importance. Such alternative centralized research facilities should be established at locations close to the existing IARCS to ensure effective integration and collaboration between the two groups.

The participants emphasized strongly the need for the closest possible collaboration between scientists engaged in crop improvement and those engaged in post-harvest research.

It was stressed that crop improvement research should be relevant to and closely coordinated with existing farming systems. Increased attention needs to be given to improved cropping systems in order to make maximum use of resources. Furthermore, the total system of crop improvement needs to be closely coordinated with animal production to ensure, for example, the most effective use of agricultural wastes and by-products.

While recommending that primary processing be included in the total post-harvest system of technologies, it is recognized that secondary processing may be more effectively assigned to institutes of food science and technology. Such research should, however, be closely coordinated with crop and animal improvement research and development.

2 Socioeconomics To make best use of existing knowledge in agriculture and food science and technology, a multidisciplinary approach should include economics, sociology, public administration, and political sciences. Staff of the IARCS should have periodic contacts with social scientists from developing countries. The social scientist could learn from the natural scientist the progress, possibilities, and potential of agricultural and food research while the natural scientist will learn of the social and political constraints to the application of their scientific discoveries.

3 Fertilizer and other agricultural chemical inputs Concern was expressed at the decreasing availability and significantly increased cost of nitrogenous chemical fertilizers derived from petroleum. Since so many of the high-yielding varieties are heavily dependent upon nitrogenous fertilizers, it was urged that the IARCS direct their attention to other means of increasing soil nitrogen through, for example, cropping systems involving cereals and legumes, and research into improving nitrogen fixation through efficient rhizobial cultures or better nodulating legumes. The complementarity of the amino acid spectra of cereals and legumes offers an added advantage of including food legumes in cropping systems.

4 Post-harvest engineering and processing There is a specific need to develop engineering systems more appropriate to the needs of tropical Asia than many of those that have been introduced from more developed economies.

Special research attention must be given to more efficient and acceptable methods of harvesting, threshing, drying, storage, and primary processing at the rural community level.

5 Manpower development The serious shortage of trained technical and managerial manpower is a matter of considerable concern throughout Asia. It is essential to identify specific types and levels of manpower requirements for each country in the region.

It was recommended that massive centralized training programs be established with international financing in existing IARCS and other appropriate institutions. These training centres would provide a group of skilled individuals equipped to assist in the development and strengthening of existing national training programs. The training programs carried on by the IARCS in agricultural technologies is well recognized. Effective regional training programs in post-harvest technologies are equally necessary.

6 Dissemination of research results While recognizing that most research workers publish their results in scientific reports and learned journals, it was felt that attention should be given to developing more effective methods of communication and dissemination of information between international and national research institutions and the agricultural, food processing and distribution communities. Operational research pilot projects may be an important strategy.

7 Livestock and dairy production Greatest research emphasis in Asia is being given to food crop improvement. The importance of integrated livestock and dairy production both as a means of increasing protein sources and employment opportunities should not be overlooked. Particular attention should be given to the greater use of agricultural and industrial wastes and by-products in animal-feeding systems.

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SESSION I PAPERS

Broad Perspectives

Joseph H. Hulse, Chairman



The Integration of Food and Agriculture Research in Asia

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Abstract This paper reviews food production in Asia, the current food problem, and the outlook for 1974. A strategy for meeting short-term food shortages is discussed as is the possible impact of the energy crisis on food production. A long-term strategy for the agriculture sector is discussed in terms of the overall economic growth and social objectives of developing countries.

Résumé Ce texte passe en revue les problèmes d'ordre alimentaire qui se posent en Asie: Production, situation actuelle, perspectives pour 1974. L'auteur expose une stratégie permettant de faire face aux pénuries à court terme ainsi que les répercussions possibles de la crise de l'énergie sur la production alimentaire. Il analyse également une stratégie à long terme applicable au secteur agricole dans le cadre de la croissance économique globale et des objectifs sociaux des pays en voie de développement.

Introduction

ANY discussion of a long-term strategy for agricultural development in Asia must necessarily be preceded by an analysis of the food problem that has emerged in the world since the middle of 1972, as the problem will probably not ease for most of 1974. It would also be useful to examine why cereals form such an important part of our diets in developing countries and how the consumption patterns compare between the developing and the developed worlds. When such a comparison is made it is seen that on the average, the daily protein and caloric requirements are not being met in most areas of the world, with shortfalls being most marked in Central Africa and the Indian subcontinent.

It is only in recent years that the food problem has been examined in terms of the nutritional content of various food crops. Lord Boyd-Orr, FAO's first Director-General, wrote that "food production was never fully developed because Western civilizations' aim was not to produce the quantity of food necessary to satisfy human needs but rather that which could be sold at a profit (Pokrovsky 1972). It was not until international efforts were directed toward examining the nutritional value of the diets of poor people in developing countries that the food problem was viewed from a different perspective and not merely one of producing a commodity which could be sold for the maximum profit.

Initial research efforts in agriculture were mainly concentrated on cereals because they

provide almost half the protein and caloric intake in the diets of people of developing countries. Accordingly, research into increasing yields and the nutritional content of cereals assumed crucial importance. In spite of these efforts which resulted in spectacular increases in wheat and rice output, cereal production in developing countries barely kept pace with population growth during the 1960s, and in 1972 food production in developing countries declined for the first time since 1966, while per capita food production dropped to the lowest level since 1965 (IDRC 1973). Food production in the developing countries declined in 1972 for the first time since 1966. Per capita food production in the developing countries dropped to the lowest level since 1965 (IDRC 1973). Therefore no margin was available to meet the demand for higher consumption levels resulting from higher incomes. Developing countries could adopt one of two courses of action: compress consumption standards below present (1974) nutritional levels or import cereals from abroad by utilizing their already low foreign exchange reserves. Where no reserves were available, large foreign debts for imports would have to be incurred.

In the past, production increases in many developing countries were achieved mainly by expanding the cultivated areas. This has of course required tremendous inputs of capital to clear and irrigate land, and settle people in the new areas. Recent studies indicate that there are, at most, 3.2 billion ha of land potentially suitable for agriculture on earth. Approximately half of that land, perhaps the richest and most accessible, is under cultivation at this time (Meadows et al. 1972). If the balance of land is to be opened up for cultivation and irrigation facilities provided, immense capital expenditures would be required which are well beyond the reach of many developing countries. Costs of developing new land vary widely and recent estimates have shown that it could be as high as \$us 5275/ha. Therefore future increases in cereal production could be achieved mainly by further increases in yields and crop intensity, i.e. by reducing the maturity time of crops. The alternative would be, as

earlier stated, to use foreign exchange reserves where available or incur foreign exchange liabilities, both of which developing countries can ill afford, to satisfy the consumption demands of both an increasing population and a population with higher incomes seeking higher living standards.

Current World Food Problems

The most important factor which led to the current world crisis in food grains was the purchase of 17.5 million tons of grain by the USSR in mid 1972, the largest-ever wheat purchase by a single country. World trade was able to expand to meet this demand by drawing down stocks of the major wheat exporting countries — Argentina, Australia, Canada, EEC and the United States. Stock levels in these countries, which amounted to 47.4 million tons at the beginning of the financial year (July 1) 1972–73, were reduced to 27.3 million tons by the beginning of the next financial year 1973–74, the lowest level since 1951–52. At the same time, drought conditions affected the production of rice and coarse grains in Asia and resulted in an additional import demand for wheat. However, because of the draw-down in stocks and sharp increase in market prices, this demand could not all be realized. At the beginning of the 1973–74 financial year, rice stocks had been reduced to virtually zero while wheat stocks were at their lowest level for 20 years and, therefore, world supplies in 1974 are entirely dependent on the success of the harvests.

Final figures of wheat production for 1972–73 show that production (excluding People's Republic of China) estimated at 310 million tons was approximately 10 million tons less than in the previous year, a decline of 3%. The main decreases in production were in the USSR by 13 million tons, the United States by 2 million tons, and Australia by 2.4 million tons, and these were partially offset by increased output in Eastern Europe and elsewhere. The volume of trade increased by 15 million tons in 1972–73 to 67.6 million tons, mainly as a result of the large purchase by the USSR. During this period, international prices increased by over twofold. The cost of a ton

of wheat FOB US Gulf Port increased from us\$60/ton (it is reported that the Soviet deal was concluded at us\$60/ton) in July 1972 to us\$110/ton in June 1973. Since the end of the last financial year wheat prices reached a peak of us\$200/ in August 1973 and stabilized at around us\$190-195 at the end of September 1973. Comparable prices are not available for the period after the end of September 1973.

In 1973-74 it is expected that production (again excluding the People's Republic of China) would increase to 325 million tons which is considered adequate to maintain balance with the increased demands from developing countries facing food shortages due to drought conditions. This increase has been achieved partly by favourable weather conditions in the main wheat growing areas and partly by actions taken by the United States to remove the mandatory set-aside provisions from its 1973 wheat program, by Canada to increase initial payments for wheat deliveries from the 1973 crop, and by the Australian Wheat Board to increase the wheat delivery quota.

In the case of rice, 90% of which is produced in Asia, unfavourable weather conditions reduced production in 1972-73 by about 10 million tons to an estimated 196 million tons, a reduction of nearly 5%. Due to monsoon failures and floods in certain areas which took place later, rice output declined all over Asia with very few exceptions. The most severely affected were India, Bangladesh, Indonesia and the Philippines while the traditional exporters, Thailand and Burma, also suffered reductions in output. The out-turn of the crop for 1973-74 is not yet known. However, the supply-demand imbalance which emerged in 1973, due to the draw-down in stocks in exporting countries to virtually zero, resulted in a sharp increase in export prices. To illustrate the price increase, the FOB price of Thai rice (5% broken) moved from us\$137/ton in July 1972 to us\$205/ton at the beginning of March 1973. No regular quotations are available since that date but it is reported that transactions were entered into by private traders for prices as high as us\$250/ton. To meet this situation, most countries in the area

have launched crash programs to increase rice production and substitute food crops such as cassava. It has also resulted in the stimulation of production in non-Asian countries such as the United States, which has announced a 20% relaxation of the rice acreage limitation that had been in force, as in the case of wheat.

Unlike in earlier years of rice shortage (e.g. 1966-67) when wheat and other coarse grain supplies from Western countries on concessional terms were substituted for rice, in the current crisis developing countries have had to face reduced supplies and higher prices of wheat. Further, freight rates have increased, both due to higher fuel costs and shortage of shipping tonnage, caused by the extraordinary transportation requirements of cereal to deficit countries. Developing countries had to face price levels in 1973 which were more than double those that prevailed earlier. It has been estimated that an additional minimum of us\$2 billion was required for food imports in 1973 over 1972, nearly a two-third increase in the food import bill of all developing countries. The additional cost of food imports by developing countries would have been greater if supplies were available to meet consumption requirements in a normal year, leave alone an increase in consumption to nutritional levels comparable to those prevailing in Western countries. The extra outlay of foreign exchange, where no substantial foreign exchange reserves were available, resulted in a cutback of allocations to other production sectors. For example, in Sri Lanka imports of rice and flour in 1972 accounted for 16% of the total import bill. In 1973 the import value of these two commodities increased by nearly 90% and accounted for 30% of the import bill. Since Sri Lanka does not have any cushion of foreign exchange reserves, this resulted in a reduction in the allocations for industrial raw materials and spares, with consequent adverse effects on economic growth.

In many cases, the enhanced draw-off of fertilizers for the numerous crash programs launched by developing countries to meet this deficit situation, have increased prices to astronomical levels. As a result, several countries of the region are unable to purchase the fer-

tilizers required for these programs due to the non-availability of foreign exchange, thereby perpetuating the vicious circle of food shortage created by the present circumstances in the world market.

Short-Term Strategy

It is no longer possible to treat the current global shortage of cereals as a phenomenon which will not happen again. As mentioned earlier, rice shortages in drought years in the past have been met by sales of concessional wheat and other grains from exporting countries in the west. In fact, the grain reserves of the major producing countries, in particular the United States, and the reserve crop land which is normally idle in the United States, and amounts to nearly 50 million acres out of a total of 350 million acres, have been the world's major reserves in battling periodic food shortages. The current shortage of wheat which had its origins in the heavy grain purchases by the USSR have made it necessary to reconsider this strategy. The USSR, India and the People's Republic of China are the three most populous countries in the world, accounting for 45% of world population and 40% of cereal consumption and they are operating close to self-sufficiency in grain production given normal weather conditions. Due to the enormity of their markets and production, year-to-year fluctuations in the production and domestic requirements could change the entire supply-demand balance of cereals in the world. For example in the case of the USSR, this is the third time in a decade that it became a net importer (vs a net exporter) of wheat in any normal crop year. In 1963-64 and 1965-66, the USSR imported a total of 18 million tons while in 1972-73, a total of 17.5 million tons was imported. Earlier purchases also had a destabilizing effect on world trade but the purchase in 1972-73, being much larger and coupled with purchases of wheat of 4 million tons by China and 2 million tons by India, made it a disastrous year for other importing countries. The situation in India would have been much worse had it not been for the buffer stock of 9 million tons of food

grains built up from periods of good harvests in earlier years. Therefore, in a situation where stocks in major exporting countries have been reduced to their lowest level in the last 20 years, it is certainly not possible to prevent any deficit of the magnitude which emerged in 1972-73 in the three largest countries of the world, from having disastrous effects on the rest of the world.

It is in this situation that the Director-General of the FAO warned the international community that temporary stockpiling of grains will not solve the long-range problems that have emerged since mid 1972. He called for international cooperation to ensure that national food stocks are maintained at adequate levels to offset year-to-year fluctuations in output and to maintain a steady expansion in consumption. Whilst this exercise would have to begin with each country setting a target level of stocks to protect itself from crop failures, an internationally managed stock control would have to take account of the distribution of these stocks, both geographically and between importers and exporters and the commodity composition of the cereals. The FAO Director-General stated recently that "the object would be for developed countries to build up stocks sufficient for their domestic requirements and for regular commercial exports and also, where appropriate, for food aid to meet crop failures or natural disasters in other parts of the world." In the case of poorer nations, they would be encouraged to gradually build up reserves to make them progressively more self-reliant in food needs. In developing countries, national stock levels should be determined only after providing for consumption levels necessary to raise them above the present inadequate levels.

The value of reserve stocks is clearly illustrated by India's experience in 1972-73, when that country was able to avoid a disastrous situation because of the 9 million tons that had been accumulated from earlier years. Yet even this stock was hardly more than a month's supply based on the current annual rate of demand of around 100 million tons of food grains. India is proposing to raise its stock target to about a 2-3-month supply at an

initial capital cost of around US\$500 million since available stocks have now been exhausted. To maintain this stock, additional annual costs would be very high. Such stock levels obviously cannot be financed by developing countries without international support. Therefore, any proposal to set up internationally controlled buffer stock would, at the same time, have to consider the financing requirements of setting up both the storage and grain reserves needed to build up such a buffer. Such international action would stabilize the world grain market since the quantities entering world trade are only a small share of the world's production of grains.

Possible Impact of Energy Shortage

Increased fertilizer usage has been a major factor in increasing yields of food crops along with the use of high-yielding varieties of seeds. The effective use of the agricultural extension services and the introduction of credit facilities for the purchase of agricultural inputs have made it possible to demonstrate to farmers the clear gains that are achieved in productivity by the application of fertilizers. About 4 years ago an excess of nitrogenous fertilizers in the world market resulted in major fertilizer manufacturers of the world exerting pressures on their respective governments to extend long-term credit to developing countries for the purchase of these excess supplies. However, the supply-demand imbalance that existed at that stage resulted in a curtailment in the expansion plans of fertilizer production by major suppliers. Further, the failure of India, a large consumer, to achieve the target for fertilizer production in the Fourth Five-Year Plan, and the higher worldwide demand for fertilizers to support the intensive food production programs of developing countries, have created a situation of shortage in the world fertilizer market. During the visit to Southeast Asia by Prime Minister Tanaka of Japan, he was urged by ASEAN countries to keep up supplies of certain critical inputs in spite of the energy crisis, one of which is fertilizers.

The shortage of fertilizers would be felt

mainly in the nitrogenous varieties, of which urea accounts for nearly 60% of the amount used in Asia. This product is at present controlled by three major manufacturing groups, one each in Japan, Europe and in the Persian Gulf. In the face of the recent sharp increase in the price of crude oil and the cutback in supplies, it is inevitable that naphtha, a by-product in the manufacture of petroleum fuels and a major input for the manufacture of nitrogenous fertilizers, would be similarly affected. In this situation, it is likely that major producers in Japan and Western Europe would be unwilling to work their plants to capacity, thereby leaving the world supply position to the response of the Persian Gulf producers to meet this shortage. The impact of the changed supply-demand position would be felt mainly in the Asia region which, apart from Japan, Korea and Taiwan, depends on imports for nearly half of its total consumption.

In this context, Indonesia, which is the largest producer of oil in the Asian region, would have a major role to play in meeting the demand for nitrogenous fertilizers in future. According to present estimates, Indonesia would require a manufacturing plant of nearly half a million metric tons of urea to be self-sufficient and only additional production capacity could fill the import needs of developing countries in the Asian region. Therefore, it is almost certain that the ASEAN group of countries would take this up as a matter of high priority in drawing up their contingency plans to meet the impact of the energy crisis on food production programs in the region.

Long-Term Strategy

There is now a greater awareness of the need for equity and social justice to be a part of the growth process in developing countries. The mere pursuit of economic growth in overall terms, as recent examples have shown, has often created social upheavals which threaten the very institutions instrumental in setting up the framework for achieving rapid economic growth. This realization has made it necessary for economic planners to examine the nature

and quality of this growth. According to statistics of income distribution available for 40 developing countries, on the average, the upper 20% of income earners receive 55% of the national income, the upper 40% receive 75% of the national income, while the lowest 20% receives only 5% of the country's total national income. This illustrates the severe inequalities that exist in the distribution of income in our societies, in spite of a rate of growth of over 5% achieved during the First United Nations Development Decade. It also shows that the rate of growth of national income is based heavily on the increase in incomes achieved by the upper income groups in our countries.

The President of the World Bank and the International Monetary Fund urged in 1973 the adoption of "a socially oriented measure of economic performance" which would give an equal weight to a 1% increase in the incomes of the poorest groups in society as to a 1% increase in the incomes of the upper echelons of society. This would be an important step in redesigning the development policies by giving a greater weight to the problems of social welfare and ensure "the allocation of resources in a much more comprehensive way." Such a statement might sound heretical to conservative bankers in the western world. Nevertheless, a word of caution is necessary to development planners, subject to the stresses and strains of active political systems, in case there is a desire on their part to pay a greater emphasis to welfare criteria. The social aspects of development should certainly not be at the expense of high investment rates necessary to achieve rapid growth in national income.

In support of this argument, Sri Lanka, which in the post-independence era of over 25 years, has followed liberal social welfare policies. For example, Sri Lanka has had extensive health services provided free of charge, education from the primary school to the university, also provided free of charge, subsidized public transportation, the issue of one pound of rice per week free to every member of the population (until early 1974 two pounds per week was issued free) and numerous other subsidies

which extend over the entire range of economic activities in that country. These welfare policies have been instrumental in reducing the disparities in income, and according to recent data made available from a socioeconomic survey of households, the top 10% of income receivers account for only 29% of total national income compared to 42.5% in 1953, and during the same period the lowest 10% of income receivers increased their share of national income from 1.5 to 4.7%. This achievement in the redistribution of income has been in marked contrast to the other developing countries in Asia, but these changes have been achieved in a period of sluggish economic growth of around 3-4% per annum. These extensive welfare programs, which in the initial stages were financed from the revenues siphoned off by government from a buoyant export sector, made serious inroads into development expenditures when world market conditions caused a secular decline in earnings of our major export crops and, in some years, fairly substantial declines in export earnings. During this period when successive post-independence governments in Sri Lanka were pursuing social welfare policies, which only developed countries of the Western world could really afford, the aspirations of the people in regard to employment opportunities and consumption standards increased because of improved educational and health standards. However, in a background of only a moderate increase in the productive capacity of the economy, there was no possibility of employment opportunities matching the aspirations of the people, and it ultimately led to a social upheaval in 1971. Such a situation clearly illustrates the need to map out a new strategy for development, in which social objectives play as great a part as that of increasing investment to achieve a faster rate of economic growth in the country. In other words, the two factors should complement one another.

In adopting such a strategy, it is clear that in Asia, as in other parts of the developing world, the main outlet for the ever-increasing numbers entering the labour force would be the agricultural sector, for on average, rural

communities in developing countries account for over two-thirds of the total population. Table 1 illustrates the current importance of the agriculture sector in total gross domestic product (and much more in terms of employment if statistics were available) for selected Asian countries. These figures show that in spite of policies aimed at achieving rapid industrialization, the agriculture sector would continue to be the most important for providing employment opportunities in the foreseeable future.

TABLE 1. Agriculture as a share of Gross Domestic Product.

	%
Philippines	31.8 ^a
Malaysia	30.5 ^b
Thailand	29.5 ^c
Indonesia	43.6 ^d
India	48.2 ^e
Sri Lanka	34.7 ^f
South Korea	31.3 ^g

^a1972: Agriculture as a share of net domestic product (Four Year Development Plan FY 1974-77).

^b1973: (Mid-Term Review of the Second Malaysia Plan 1971-75).

^c1971: (The Third National Economic & Social Development Plan 1971-76).

^d1971: GDP at current market prices (Indikator Ekonomi. Monthly Statistical Bulletin Oct. 1973).

^e1969 GDP at current factor prices (UN Statistical Year Book for Asia and the Far East).

^f1972: (1972 Annual Report — Central Bank of Ceylon).

^g1970: (UN Statistical Year Book for Asia and the Far East).

If one examines the agriculture sector closely, the first striking feature is the fragmented nature of farm holdings. A recent FAO survey has shown that the wealthiest 20% of land owners in most developing countries own between 50 and 60% of the total crop land, and in countries such as Venezuela, it is as high as 82%. Further, tenancy arrangements are enforced which make it necessary for

farmers to hand over more than 50% of their crop to absentee landlords. Given such a distribution of land ownership and tenancy arrangements, the fruits of the Green Revolution of the 1960s could not obviously be reaped by the small-scale farmers who were struggling against adversity for survival. Despite the rapid increases achieved in the production of agricultural crops by the introduction of high-yielding seed varieties, the lack of ready access to credit, agricultural inputs, and other facilities made it impossible for the small subsistence farmers to enjoy the full benefits of the Green Revolution. Further, the fiscal policies of the governments in developing countries have been helping the wealthier farmers. Overvalued exchange rates and ready access to credit at low rates of interest made it possible for the larger landowners to indulge in excessive mechanization earning larger incomes from the rapid increases in production, thereby accentuating the inequalities that already existed in this sector. At the same time, these policies were in conflict with those designed to provide employment opportunities for the large numbers entering the country's labour force.

Thus it is clear that the new strategy for development should have policies designed to accelerate the pace of land reforms and land distribution. These should be coupled with programs to provide greater access to credit, greater availability of agricultural inputs such as fertilizers, and extensive irrigation facilities where none exist at present. In other words, what is proposed is not a perpetuation of the lot of the traditional subsistence farmer, but an improvement in the image and prospects of this sector which would attract the young, educated masses entering the labour force to participate in the improvement of this traditional sector.

Agricultural research and extension services have a major role to play in achieving an increase in the productivity of the small farmers. The inadequacy of the extension services in developing countries could be illustrated by the fact that on an average one extension officer is available for over 400 farm families in the developed world, while the ratio is one

to over 8000 farm families in the developing world, with even fewer available to the small subsistence farmer. To correct this imbalance, additional funds have to be allocated by governments of developing countries to train a larger number of agricultural extension officers, and to provide adequate career incentives for the educated youth to seek such jobs. In regard to research the imbalance is even greater. In spite of the prognostications of the Club of Rome (Meadows et al. 1972) that man would soon be battling with physical barriers to increase food production, the research efforts which initiated the Green Revolution provide us with confidence that improved technologies can solve the massive food problem that has been forecast for the future. However, the following comparison will illustrate the inadequacy of research efforts in developing countries. Governments of five major developed countries are allocating us\$20–50 per farm family for research purposes annually, whereas the comparable average for five major developing countries is in the range of us\$0.50–2 per farm family (Meadows et al. 1972). To illustrate this further, McNamara observed that the United States, Northern Europe, Australia, Israel and Japan spend an equivalent of between 1 and 3% of agricultural commodity value on research, whereas the percentage is between one-tenth and four fifths of 1% in the developing countries of Asia and South America. It was this overall disparity in research efforts that prompted the World Bank, in coordination with the FAO and the UNDP, to sponsor the setting up of a Consultative Group on International Agricultural Research (CGIAR). Since the first meeting of this Group in May 1971, a number of international centres have been set up with support from the Group, including the IDRC, directing research efforts into new areas. At the time the Consultative Group was set up, five international centres were in existence: 1) CIAT — Centro Internacional de Agricultura Tropical (Bogota, Colombia) — Cassava; 2) CIMMYT — Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico) (International Maize and Wheat Improvement Centre) — Maize, Wheat and Triticale; 3) CIP — International

Potato Centre (Peru) — Potato; 4) IRRI — International Rice Research Institute (Philippines) — Rice; 5) IITA — International Institute of Tropical Agriculture (Ibadan, Nigeria) — Sweet Potatoes and Yams. Since the setting up of the Consultative Group, the following centres have been created: (a) ICRISAT — International Crops Research Institute for the Semi-Arid Tropics (Hyderabad, India) — Sorghum, Millet and Legumes; (b) ILRAD — International Laboratory for Research on Animal Diseases (Kenya) — Livestock; and (c) ILCA — International Livestock Centre for Africa (Proposed) (Ethiopia) — Livestock.

Conclusion

In conclusion I would like to refer briefly to some of the agricultural research projects supported by IDRC in Asia. The first is a recent grant of Can\$90,000 approved for a research study by the University of Brawijaya in East Java for the development of cassava production combining the tree and normal cassava. The system, which was discovered over 20 years ago by a poor farmer in the East Java region, is expected to increase yields by at least five to six times, compared to the normal average of 5–15 tons/ha. This research project would also enable Indonesia to be linked to the cassava research network that is administered by the IDRC and based at the Centro Internacional de Agricultura Tropical in Colombia. A related project is one undertaken by the University of Malaya with IDRC support to develop fermentation processes for upgrading starches such as tapioca roots for use as swine and poultry food. The second is a grant of Can\$496,000 to the International Crop Research Institute for the Semi-Arid Tropics at Hyderabad for research activities to develop better varieties of pigeon pea and chick pea, which are fertilizer-responsive and better adapted to the conditions prevailing in semi-arid tropics, and to train research and extension workers in the improved technologies of production. This institute, which commenced operations in 1972, was the sixth international

agricultural research institute that was set up, and it is concerned with the development of sorghum, millet, and legumes on a worldwide basis. The third example I would like to quote is a grant of Can\$230,800 to the International Rice Research Institute in the Philippines to develop the basic technological knowledge required for the introduction of multiple-cropping systems to small farms. This grant enabled a continuation and expansion of a study which had been initiated by IRRI and the University of Philippines, Los Baños, and also enabled six pilot projects to be set up in the Philippines to test the results achieved earlier, but under actual field conditions. The IDRC recently approved a further grant of Can\$442,950 for a second phase of this project to enable IRRI to continue their program of research work and to add a further six pilot communities. Apart from studying the basic technological conditions for multiple-cropping systems, the program also provides for training young scientists from countries in the Asian region. At the same time, the IDRC has also provided a grant of Can\$208,300

to Kasetsart University in Thailand to develop multiple-cropping systems in the Central Plain of Thailand, and it is likely that similar projects would be developed in other countries of the Asian region. These are but a few examples of IDRC efforts at developing international research programs designed to improve the well-being of rural communities, and enable farmers in the developing world to increase their incomes above the subsistence levels that presently prevail.

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Agricultural Research and Economic Development

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Abstract Despite the overwhelming increases in food production through research into new varieties and increased yield through use of fertilizers (the Green Revolution), millions of people in the world are still hungry. The factors involved in this paradox are discussed: the increase in population, the widening gap in the distribution of income and consumption, the complex causes of droughts (e.g. overgrazing and the expansion of arid areas like the Sahara), wars, unrest and banditry, shortage of land and adverse land tenure systems, inertia, ignorance and stubbornness of agriculture extension workers, and poor planning in industrial processing. Solutions are discussed and samples such as the MaeKlong Integrated Rural Development Project are used to show what can be done. The concept is to show the farmers how to help themselves and each other in the form of cooperatives.

Résumé Des millions d'hommes souffrent encore de la faim dans le monde, alors que les recherches relatives à la création de nouvelles variétés, les augmentations de rendements dues à l'emploi des engrais (Révolution Verte) ont accru d'une façon extraordinaire la production alimentaire mondiale. L'auteur passe en revue les différents facteurs de cette situation paradoxale: l'explosion démographique, les écarts sans cesse croissants dans la répartition des revenus et de la consommation, les causes complexes des sécheresses (p. ex. le surpâturage et l'expansion des zones arides comme le Sahara), les guerres, l'agitation et le banditisme, le pénurie de terres arables et les régimes fonciers défavorables, l'inertie, l'ignorance et l'entêtement des vulgarisateurs agricoles, le manque d'organisation des systèmes de transformation. L'auteur évoque un certain nombre de solutions et d'exemples, comme le Programme de développement rural intégré du MaeKlong, lequel démontre ce qui peut être réalisé. Cet ouvrage a pour objet d'indiquer aux agriculteurs comment ils peuvent s'aider eux-mêmes et comment ils peuvent s'entraider en formant des coopératives.

THE strategy for the United Nations Second Development Decade prescribes the following objectives; among others:

- (a) increase in the real income per capita;
- (b) redistribution of income in favour of the poor;
- (c) social justice; and
- (d) prevention or

reduction of unemployment and underemployment.

Researches in agriculture and food science constitute a very important means of attaining these development objectives. An increase in agricultural productivity would tend to im-

prove the income of the farmers, the most numerous underdogs of the developing world. By increasing the world food supply and ensuring an efficient means of distribution, famine and hunger could be prevented. Improvement of the nutritive quality of food, especially for infants at crucial stages of growth, should not only enable poorer people to enjoy better health, but also it would tend to have a beneficial and long-lasting impact upon the mental and physical abilities of the new generation. In general, we should expect successful research generally to improve the quality of life both in the rural and urban areas.

Recent studies in agriculture and food science have indeed produced staggering results. The scientific discoveries in the field of rice, wheat, and other crops have been hailed as miraculous, and there are more to come: for example, the crossing between wheat and rye to produce a new food crop called triticale, a research project financed by the International Development Research Centre. The promise is likely to be fulfilled. The Green Revolution is with us and Utopia may yet be realized!

Yet, even today, there are large areas in the world where hundreds of thousands of people die from famine, and still more who go to sleep hungry every night. Malnutrition still takes its toll among millions of children and adults. Even those who have enough to eat in the rural areas and in large sections of the urban areas are still heavily weighed down with poverty. World prices of food grain, meat, animal feed, and fish continue to increase. River and atmospheric pollution is no longer confined to the cities of the rice-growing nations; it is spreading to the countryside as well in the developing world. All these problems are not short-term or periodic problems; the long-term outlook is even dimmer.

How could this apparent paradox be explained? I think that the reason behind this paradox is the fact that in the present human society, scientific progress is far more advanced than our wisdom to utilize this gain in technological knowledge. Our commercial and economic system, our skill in public administration, our social organization all lag behind

and remain inadequate to cope with the complex task imposed by more advanced technology.

The rapid growth in *population* during the past century has outstripped the increase in food production. This is indeed a global problem; but worse still, the rate of population growth has been highest where productivity improvement has been the lowest, i.e. in the poorest regions of the world. Family planning and birth control are necessary to ensure an adequate food supply.

Secondly, *the widening gap in the distribution of income and consumption* between the rich and the poor in this world militates against the poor in respect of their food consumption. The rich in developed and developing nations alike, in New York, London, Tokyo, Singapore, or Bangkok consume more meat and better quality meat than ever before; and consequently the extra amount of food grain necessary for producing more and better livestock and poultry has been obtained at the expense of the supply of food grain for the poor.

Thirdly, for some complex reasons, including *overgrazing* in equatorial African regions, the areas of some deserts like the Sahara have expanded through long years of droughts. This phenomenon, coupled with the fault in the distribution system and the absence of sufficient weather-monitoring service, has caused serious famine in many countries in Africa and in Asia.

Fourthly, *wars, unrest, banditry* seriously disrupt the normal food supply distribution system and gravely deter investment and production. In the words of senior cattle officers in Thailand, relatively peaceful in Southeast Asia, "We have not the heart to urge farmers to breed more livestock, knowing full well that sooner or later the cattle will be stolen and no remedy is in sight."

Fifthly, in many poorer countries, the *shortage of land and the adverse land tenure system* and the consequent absence in the improvement of land for cultivation have caused the productivity of land to progressively deteriorate over the years. The problem of land tenure is cumulative, because, more and more

owner-farmers are losing their land every year through indebtedness. This problem is aggravated by the vagaries of weather and by the instability of the price of agricultural products.

Sixthly, in many instances, the *inertia, ignorance, and stubbornness of agricultural extension officers* constitute formidable resistance to the application and dissemination of modern scientific knowledge needed in the concept of the Green Revolution.

Seventhly, *industrial processing of agricultural products often suffers from faulty planning* with respect to the supply of raw materials. Pineapple canning factories, for example, too often rely on chancy supplies of pineapple from neighbouring small farms and consequently have to interrupt their production when inadequate supplies are forthcoming.

There are no doubt other reasons for the unsatisfactory situation in the application of scientific knowledge for the benefit of mankind. But the major problems appear to lie in our inability to organize our social, administrative, and economic system to match our technological progress.

Possible Solutions

If the above analysis is correct, the problem must be tackled simultaneously at several levels; by international cooperation, by national governments, and by organizations within each nation.

International actions are needed for the prevention of war, monitoring bad weather, for arresting the expansion of aridity and extreme aridity, for the stabilization of agricultural prices, and for fairer distribution of food supplies between poorer and richer nations.

Governmental measures should aim at maintaining law and order within the nation, for population control, for fiscal policy in favour of more equitable distribution of income, for reform of land ownership and land tenure, for better irrigation and water supplies, and for better service of agricultural officers.

Within each developing country, there is great scope for action by non-governmental organizations, such as universities, or private charitable movements, to go out in the rural

areas and supplement government services. In most developing countries, there is a wide gap in the communication between officials and farmers. The former are inert and usually stand-offish; the latter do not have confidence in government officials. University teachers and students (see The Maeklong Project section) and private voluntary workers (such as the Philippines Rural Reconstruction Movement and the Thailand Rural Reconstruction Movement) could usefully serve as important links between officialdom and the populace in the short-term, and in the long-term urge the government to climb down, and the farmers to climb up so that the two should meet on equal footing.

Whatever the case, national development is a multidisciplinary process. Research planning must cover all aspects of human life and human society. Agriculture and food research must go hand in hand with researches in health including family planning, in education, in administration, in economic fiscal and commercial policy, and in social policy. Knowledge in agriculture and food, in social science, in administrative art, in medicine, and in education must be integrated or at least coordinated, so that their application to a village, a district, a province or a nation should bear the greatest benefit to man and to human society.

The Maeklong Project

At present, in Thailand, three universities are jointly planning to launch a project, called the Maeklong Integrated Rural Development Project. The three universities are: Kasetsart (agriculture), Mahidol (medicine), and Thammasat (social science). The geographical location of the project is the area, west of Bangkok, confined by the Ta-Chin river in the East, and the Mae Klong (the famous river "Kwae") river in the West. The total area is some 1.5 million ha, with some 2 million people. In this area, there are a variety of crops including rice, fruits, sugar cane, cassava, also livestock breeding in the hilly parts, and sugar mills in the West.

The principal concept of the project is to help the farmers to help themselves, and to help each other in the form of cooperatives.

The approach will be an integrated interdisciplinary one: i.e. agriculture and food, health including nutrition and family planning, education and social sciences. In order to gain the confidence of the villagers, university teachers and students will form a number of small teams and go and live in the villages, as ordinary citizens, and mix with the villagers. Whatever the universities could do to help the villagers with their own resources, they would proceed to do so. But for bigger problems requiring greater resources beyond the capacities of the universities, the matters will be referred to the government. For this purpose, the management of the project will have to make good

contact with government departments as well as with government officials in the field.

After 3–5 years, the project will be evaluated and assessed. The lesson of successes and failures in this experiment might be used and generalized for application to other areas of the Kingdom. It is felt that, after 10 years of infrastructure development in Thailand, in which the overall rate of growth has been about 8–10% per annum on the average, the main defect of the government's developmental efforts has been that the benefit of the development plans has not reached the poorer people in the rural areas. It is hoped that this new project will help to correct this past defect.

SESSION II PAPERS

Crop Improvement

James Johnston, Chairman



Current Programs of the International Rice Research Institute

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Abstract IR8, the first variety named by the International Rice Research Institute (IRRI) represented a new plant type; it has a short and stiff straw, erect leaves, and the capacity to tiller heavily. Since the release of IR8 in 1966, a series of new varieties have been named: IR20, IR22, IR24, and IR26. These combine the IR8 plant type and its responsiveness to fertilizer with higher grain quality. IR26 is resistant to major diseases and insects. Twenty-six IRRI breeding lines have been named as local varieties and released for commercial cultivation by nations in Asia, Africa, and Latin America. Some countries have developed and released their own varieties through national breeding programs. Average yields in several countries are steadily rising as more farmers plant modern semi-dwarf varieties.

The modern varieties will reach their yield potentials only if farmers use improved cultural practices, including optimum application of fertilizer, water and weed control, and protection of crops from pests.

Nitrogen, phosphorus, and potassium (NPK) are the major nutrients used by rice. Other soil deficiencies, however, may greatly reduce the yield response to N, P, and K. IRRI scientists showed that rice grew poorly in certain areas, and did not respond to NPK, because of zinc deficiency. Fertilizer response is also dependent on good water control.

The payoff from good weed control increases sharply when farmers adopt high yielding varieties. The Institute identified several cheap herbicides for weed control. The low-cost herbicide 2, 4-D effectively controls weeds if applied 4 days after transplanting rice. Butachlor controls weeds in direct-seeded and upland rice.

IRRI has evaluated hundreds of insecticides. In early work, granular insecticides applied to paddy water were far more effective than foliar sprays. Recently, insecticides placed in the root zones proved even more effective than paddy water application. Engineers and entomologists are developing a practical method for root zone application.

Improved varieties and intensive cropping have increased the economic advantage of rice mechanization. The Institute engineering program emphasizes the design and development of machines for small-scale farmers. A simple power tiller was developed which can be easily fabricated in the developing countries. The Institute also designed and released other machines including the axial flow thresher, the batch drier, and the multihopper seeder.

The Institute is trying to determine exactly why yields are lower on farmers' fields than on experiment stations. Some constraints to production are environmental; others are due to poor management. Farmers can appreciably increase their yields by using a package of practices which includes fertilizer, water management, and pest and weed control. In one area in the Philippines, insect control alone accounted for two-thirds of the yield differences between recommended practices and farmers' actual practices.

Several production constraints can be removed or their adverse effects minimized through genetic improvement of varieties. Small-scale tropical farmers are generally unwilling to take risks and to invest in inputs. Scientists have identified varieties in the world collection that are resistant or tolerant to insects, diseases, drought, deep water, low temperatures, and adverse soil conditions. IRRI is currently concentrating research to develop varieties with built-in resistance to these adverse conditions in order to lower the costs and reduce the risks of producing high yields.

The Institute shares new information and material generated by its research with national rice programs. Through cooperative projects, the Institute helps national programs enhance their capacities for rice research.

Résumé La première variété de riz à laquelle l'Institut International de Recherches sur le Riz (IRRI) ait donné un nom, l'IR8, représente effectivement un nouveau type de ce végétal; il a une tige courte et solide, des feuilles érigées et possède des capacités de tallage élevées. Une série de nouvelles variétés a vu le jour depuis que l'IR8 a été mis en circulation en 1966: IR20, IR22, IR24 et IR26. Ces variétés combinent une meilleure qualité du grain aux caractères végétaux de l'IR8 et à ses facultés de réponse à la fumure. L'IR26 est résistant aux maladies et aux insectes principaux. L'IRRI a donné une appellation à 26 lignées sélectionnées à titre de variétés locales et mises en circulation pour la production commerciale en Asie, en Afrique et en Amérique latine. Un certain nombre de pays ont créé et ont mis en circulation des variétés qui leur sont propres et ce, grâce à des programmes nationaux de sélection. Dans plusieurs pays, les rendements moyens sont en augmentation constante du fait que les agriculteurs utilisent de plus en plus des variétés modernes demi-naines.

Les rendements potentiels de ces variétés modernes ne pourront être atteints que si les agriculteurs ont recours à des méthodes culturales meilleures: épandages d'engrais optimaux, désherbage, maîtrise de l'eau, protection des cultures contre les parasites.

Les principaux éléments nutritifs utilisés par le riz sont l'azote, le phosphore et la potasse (NPK), mais des carences du sol en d'autres éléments peuvent limiter dans une grande mesure les augmentations de rendement répondant à l'utilisation de N, P et K. Les spécialistes de l'IRRI ont démontré que le riz végétait fort mal dans certaines régions, et ne répondait pas à NPK et ce, du fait d'une carence en zinc. La réaction du riz à la fumure dépend également de la qualité de la maîtrise de l'eau.

Les bénéfices dus à un désherbage de bonne qualité augmentent nettement lorsque les exploitants adoptent des variétés à rendement élevé. L'Institut a identifié dans ce domaine plusieurs herbicides peu onéreux. Le 2.4-D, qui n'est pas coûteux, est un désherbant efficace si les épandages sont faits 4 jours après le repiquage. Le Butachlore convient bien aux semis en place et à la riziculture de montagne.

L'IRRI a également testé des centaines d'insecticides et a constaté que les insecticides granulaires épandus précocement dans les eaux de rizières étaient infiniment supérieurs aux pulvérisations foliaires. On a constaté récemment que l'épandage d'insecticides dans la zone des racines était encore plus efficace que l'épandage dans l'eau de rizière. Techniciens et entomologistes sont en voie de mettre au point une méthode pratique d'épandage dans la zone des racines.

L'amélioration des variétés et l'intensification du mode de culture ont accru les avantages économiques de la mécanisation de la riziculture. Le programme du génie rural de l'Institut s'est penché sur la conception et sur la mise au point de machines convenant à la petite exploitation. Il a permis de mettre au point un motocultivateur pouvant facilement être construit dans les pays en voie de développement. L'Institut a également conçu

et mis en circulation d'autres machines agricoles dont une batteuse à écoulement axial, un séchoir discontinu et un semoir à trémières multiples.

L'Institut tente de déterminer exactement pour quelles raisons les rendements des agriculteurs sont inférieurs à ceux des stations expérimentales. Un certain nombre des contraintes pesant sur la production sont d'ordre écologique, d'autres sont dues au manque de qualité des gestionnaires des exploitations agricoles. Les agriculteurs ont la possibilité d'accroître considérablement leurs rendements en mettant en oeuvre un ensemble de techniques dont l'emploi d'engrais, l'utilisation rationnelle de l'eau et la lutte contre les parasites et les adventices. Dans une région des Philippines, les traitements antiparasitaires ont donné lieu à eux seuls aux deux tiers des augmentations de rendements dues à l'emploi des techniques recommandées de préférence aux méthodes traditionnelles.

Il est possible de se libérer de plusieurs de ces contraintes de la production ou d'en minimiser les effets et ce, grâce à l'amélioration génétique des variétés. Les petits agriculteurs des tropiques sont en général très réticents lorsqu'il s'agit de prendre des risques ou d'investir dans des facteurs de production. Les spécialistes ont identifié, parmi le matériel génétique mondial, des variétés résistantes ou tolérantes aux insectes, aux maladies, à la sécheresse, aux excès d'eau, aux basses températures et à la mauvaise qualité des sols. L'IRRI concentre actuellement ses recherches sur la création de variétés autorésistantes à ces conditions défavorables et ce, afin d'abaisser les coûts et de réduire les risques inhérents aux rendements élevés.

L'Institut fait bénéficier les programmes nationaux des renseignements et du matériel végétal nouveaux émanant de ses recherches ayant trait à des programmes nationaux sur le riz. Grâce à des projets communs, il permet aux programmes nationaux de développer leurs moyens sur le plan des recherches consacrées au riz.

RICE yields are low in tropical Asia, where more than 70% of the world's rice is grown and consumed. Although several Asian nations have conducted research on rice since the beginning of this century, improvements in yields of traditional varieties were only marginal. In fact, high-yielding varieties offered little advantage in traditional rice culture, in which little or no fertilizer was used. During the same period, however, Japan and other temperate countries had markedly increased national yields through the combined use of high-yielding varieties, fertilizers, and other inputs.

During the last two decades rice-growing nations have recognized that available land in Asia for extending rice cultivation is limited, so much of the additional rice required must be obtained by increasing yields per unit area. Some national programs started the development of varieties that respond well to fertilizer and are resistant to lodging (falling over). In 1962, the International Rice Research Institute began concentrated research to develop new rice varieties and the associated technology to increase yields. I will only talk about research oriented to major rice production

problems, significant contributions that have already been made, and the current emphasis to overcome constraints to increased productivity on farmers' fields. I will primarily deal with results obtained by IRRI scientists, but I will also refer to cooperative work in different countries.

Modern Rice Varieties

The traditional tropical varieties of rice are tall and leafy. Their yielding capacity is limited because when fertilized, they grow excessively tall and fall over. The Japanese rice breeders developed fertilizer-responsive varieties that are relatively short, have stiff straws, and narrow, erect leaves. The "japonica" or temperate zone varieties, are not generally adapted to the tropics.

The first semi-dwarf fertilizer-responsive "indicata", or tropical rice variety, Taichung Native 1, was developed in 1956 in Taiwan. But Taichung Native 1 was not fully evaluated in other rice-growing countries nor were its merits as a variety responsive to fertilizer clearly recognized outside Taiwan, until 1962 when IRRI began to critically test this variety.

In 1964, trials at the Institute showed Taichung Native 1 to be one of the highest yielding varieties. Taichung Native 1 was grown commercially in India beginning in 1966 but it attracted little attention in other countries, primarily because it was susceptible to diseases.

The Institute's breeding program started with the clear objective of developing tropical varieties with improved plant type that would make efficient use of soil nutrients, solar radiation, and other inputs. Taichung Native 1 and two other semi-dwarfs from Taiwan were crossed with tropical varieties; less than 4 years later, in 1966, the Institute named its first semi-dwarf variety, IR8. The new rice was an improvement over Taichung Native 1 not only because it was more responsive to applied nitrogen (Fig. 1) but also because it was more resistant to diseases. IR8 rapidly spread throughout Asia, particularly in India, Pakistan, the Philippines, Bangladesh, and Vietnam (Athwal 1971).

IR8 represented a new plant type with short and stiff straw, erect leaves, and capacity to tiller heavily. This plant type essentially doubled the yield potential of the rice plant. IR8 was also non-sensitive to daylength, so it could be grown at any time of the year. IR8 was deficient, however, in grain quality. Its grains are bold and chalky. They cook dry and fluffy. Although people in the Indian sub-continent prefer rice which cooks dry, those

in the Philippines, Indonesia, and some other countries prefer rice which has a soft texture. Another variety, IR5, was named in 1967. Its grain quality is similar to that of IR8.

After demonstrating that rice varieties with high yield potential can be developed for the tropics, the Institute concentrated on improving the grain quality. Since then, a series of new varieties have been released which combine the high yield potential of IR8 with good grain quality. Grains which are long or medium-long, slender, clear, and translucent are preferred by consumers in tropical Asia. The cooking quality of rice depends primarily on the amylose content of the grain. Rices with low and intermediate amylose content are soft-textured on cooking, but those with high amylose content cook dry and fluffy. All of the new varieties, IR20, IR22, IR24, have clear, translucent and attractive grains; IR20 and IR22 have high amylose content whereas IR24 has low amylose content. The grains of IR20 are medium-long and slender, whereas those of IR22 and IR24 are long and slender.

Although IR22 and IR24 have high yield potential and excellent grain quality, farmers' acceptance has been limited because they are susceptible to some diseases and insects. On the other hand, IR20, which has a somewhat lower yield potential but a broad spectrum of disease and insect resistance, rapidly spread to many new countries. Today it is the most popular variety in the Philippines, South Vietnam, and Bangladesh. This demonstrates that disease and insect resistance is an indispensable characteristic which must be incorporated in new varieties to ensure their widespread dissemination.

In November 1973, the Institute named a new variety, IR26, (IRRI 1974). IR26 is resistant or moderately resistant to the major insects and diseases of rice in tropical Asia (Table 1). This resistance should be especially helpful to farmers who cannot buy extra pesticides to combat outbreaks of insects. IR26 is resistant to brown planthoppers and green leafhoppers, and moderately resistant to stem borers. IR26 is the first IRRI variety to be highly resistant to the brown planthopper, which causes severe damage in the Philippines,

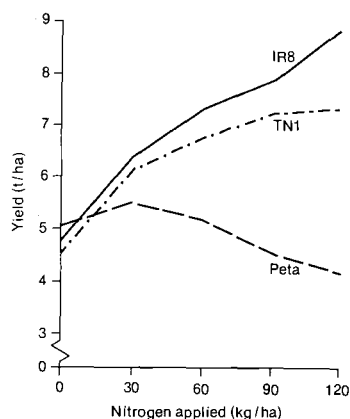


FIG. 1. Effect of plant type on nitrogen response (3-yr dry season average).

TABLE 1. Reactions of IRRI varieties to major diseases and insects.

Variety	Blast	Bacterial blight	Bacterial streak	Grassy stunt	Tungro	Green leaf-hopper	Brown plant-hopper	Stem borer
IR8	MR ^a	S	S	S	S	R	S	MS
IR5	S	S	MS	S	S	R	S	S
IR20	MR	R	MR	S	R	R	S	MS
IR22	S	R	MS	S	S	S	S	S
IR24	S	S	MR	S	MR	R	S	S
IR26	MR	R	MR	MR	R	R	R	MR

^aR, resistant; MR, moderately resistant; S, susceptible.

South Vietnam, India, and Sri Lanka. It is also resistant to tungro and bacterial blight, widespread diseases in Asia. It is moderately resistant to grassy stunt virus and rice blast diseases. IR26 has a slightly higher yield potential than IR20 because of its stronger stems, which resist lodging. Its grains are clear, slender, and medium in length, comparable to those of IR20. For tropical Asian tastes, its eating quality should be slightly better than that of IR20 and substantially better than that of IR8.

The new semi-dwarf varieties, with modern management practices, have consistently achieved yield levels very much higher than those of traditional and tall varieties. The IRRI varieties have been accepted over wide areas in several countries. But even more important has been the introduction into national research programs of genetic material with improved characteristics. Since 1965, the Institute has supplied 80,000 seed packets of improved genetic lines to more than 100 rice-growing countries and territories. To date, at least 26 of the IRRI lines have been released for commercial cultivation in Asia, Africa, and Latin America. National programs in India, Indonesia, Sri Lanka, Philippines, and Bangladesh have also developed and released their own semi-dwarf varieties for cultivation.

In 1971-72, an estimated 12 million or more hectares in tropical countries of South and Southeast Asia (15% of the total rice area) were planted to modern rice varieties. About 0.6 million hectares out of the total rice area of 6.5 million hectares in Latin

America are planted to varieties developed from the genetic material supplied by IRRI. Average rice yields in several Asian countries are now rising.

Country	Yield (kg/ha, approx.)	
	1961-64	1971
Pakistan	1400	2400
India	1520	1710
Indonesia	1800	2200
Philippines	1240	1720
South Vietnam	1860	2280

A large part of the yield increases can be attributed to the cultivation of modern rice varieties and the use of fertilizers. The adoption of new varieties and the associated technology must, however, be greatly increased to have a real impact on production.

The cereal protein of rice is of good quality because it has a relatively high lysine content (4%). But rice has a low level of protein. The protein content of milled rice averages about 7%. Increasing the protein content of modern varieties is a major objective of the Institute's varietal development program. The protein content is markedly influenced by environment, but Institute scientists have gathered evidence to indicate that the protein content of high-yielding varieties can be genetically increased by at least one-fourth. If high protein varieties are to be accepted by farmers, however, they must yield as well as the ones they would replace, and should be equally acceptable to consumers. Studies on the nutritive

values of rices with varying protein contents have shown that the net utilization of protein increases as protein content in milled rice increases, up to 10% protein. An increase in the protein content of the rice grain would not adversely affect its cooking and eating qualities. IRRI scientists have identified an experimental line IR480-5-9, which combines the improved plant type with a protein content of 9-10%. It has not been released for commercial production (except in Fiji), however, because it is susceptible to some diseases and insects. Improved lines that have a protein content and yield potential comparable to IR480-5-9, and that also are resistant to several diseases and insects, are now undergoing preliminary evaluation.

Cultural Practices

Improved cultural practices must be used to enable the new varieties to express their full yield potential. Such practices as land preparation, time of planting, and spacing are generally well understood. Recent research has been concentrated on fertilizer application, water use, and weed control.

Nitrogen, phosphorus, and potassium (N, P, and K) are the major elements needed for plant growth. A crop of rice that yields 5 t/ha removes about 100 kg of N, 20 kg of P, and 120 kg of K from the soil. Most rice soils contain adequate potassium for crop growth; the potassium supply is continuously replenished in many soils by the incorporation of rice straw, and the use of irrigation water, which has a high potassium content. Nitrogen is the most important nutrient that limits rice production, although phosphorus must also be added in many areas. Long-term fertility experiments conducted by Institute agronomists indicate that soils that continuously receive nitrogen may become deficient in phosphorus as well as in potassium under intensive cropping.

Commercial fertilizers offer a large potential for increasing rice production in the developing countries. But fertilizers are costly, particularly since the world oil crisis has caused their scarcity. Current research in IRRI's

soil chemistry and agronomy departments is focussing on increasing the efficiency of nitrogen utilization. Water management markedly influences the nutrient balance in the soil. Nitrogen is often lost through denitrification, particularly when flooded rice land dries during the growing season. We now know that continuous soil submergence minimizes denitrification. Under rainfed conditions or with poor water management, a split application of nitrogen has been found to be more beneficial than a basal application (IRRI 1974).

Plants may fail to respond to fertilizer in some soils because of a deficiency of micro-nutrients. Institute soil chemists found that zinc deficiency limits yields on thousands of hectares of alluvial soils in two provinces of the Philippines that are well supplied with major nutrients and water. Field experiments at six rice farms in this region showed that, in the absence of zinc application, NPK fertilizer either had no effect or depressed the grain yield (IRRI 1973). Averaged for all levels of nitrogen, phosphorus, and potassium, response to zinc was as high as 2.4 t/ha, the minimum yield for the zinc-only treatment for the six locations was 4.47 t/ha. The zinc treatment costs less than \$2 per hectare. It consists of dipping the seedlings in a 2% suspension of zinc oxide in water just before transplanting. Experiments were also conducted on abandoned land that is topographically well suited to rice cultivation to determine whether these lands, which have a dense growth of weeds, could be made productive by the application of zinc. The application of NPK fertilizer did not increase yields. Zinc alone, however, increased the yield of IR20 by 3 t/ha—from 2.4 t/ha without zinc to 5.4 t/ha with zinc.

The lack of adequate water is an important yield-limiting factor. Institute agronomists have demonstrated that continual flooding is not essential for high grain yield. As long as the soil remains well saturated with water, optimum yields can be obtained. However, standing water helps control weeds. If irrigation water is available, 5–7 cm of water is sufficient on most soils for weed and insect control with granular chemicals, for high nutrient availability, and for minimum losses

of nutrients from fertilizer and soil. Greater water depth may reduce tillering and induce lodging. Moisture stress at any growth stage will lower yields.

Nearly half of the world's rice is grown without irrigation, under lowland rainfed conditions. Institute rice production specialists have conducted experiments on farmers' fields under rainfed conditions. They have demonstrated that rice that is direct-seeded, rather than transplanted, at the beginning of the rainy season uses rain water more efficiently. The monsoon rains in the Philippines usually begin in May but farmers seldom have enough rain water to prepare the land for transplanting until July or August. Transplanting itself is often delayed until August. Seedlings in the nursery, or seedbed, may pass the optimum age for transplanting. But experiments on farmers' fields have shown that the crop can be directly seeded at the beginning of the rainy season. Yields of 4 t/ha can be obtained on the unpuddled soils. Using short-season rice

varieties, two rice crops can be grown under rainfed conditions (Fig. 2), or a crop of rice can be followed by other crops that require less water.

The experimental plots were established on farmers' fields at nine different sites in Central Luzon, Philippines, from mid-May until mid-June 1973 (IRRI 1974). The first plots of early maturing varieties were harvested during the second half of August, when about 40% of the paddies in the area had not even been transplanted. Not enough rain had fallen for farmers to plow and puddle the soil. An early maturing selection, IR1561-228-3, averaged 5.33 t/ha at nine locations. Seedbeds for the second planting were prepared 2½ weeks before the anticipated date of harvest of the first crop. The soil was plowed and puddled and rice was transplanted as quickly as conditions permitted. The second crop was harvested at about the time that local farmers were harvesting their first (and only) crop. Direct seeding of early maturing rice, followed by a second

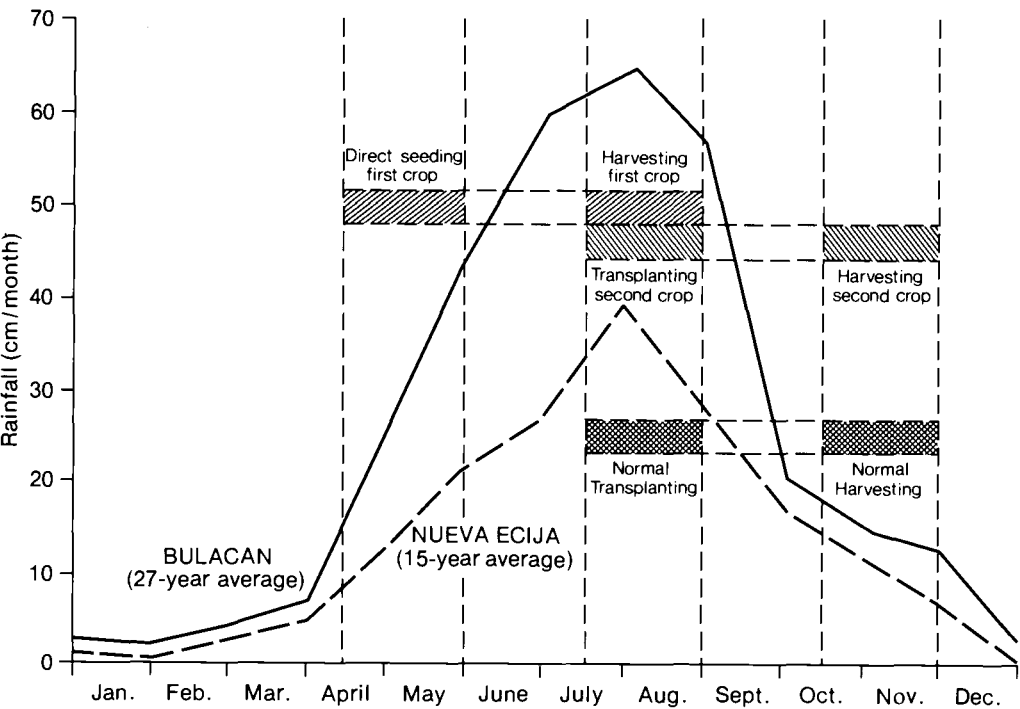


FIG. 2. Monthly rainfall in Bulacan and Nueva Ecija, Central Luzon, Philippines, with planting and harvesting periods shown for the normal transplanted crop and the two crop system.

crop of rice, corn, or grain legume, promises to become a commercial practice that will use available rain water more efficiently.

The payoff from good weed control increases sharply when farmers adopt high-yielding varieties. Handweeding is very laborious and time consuming. Even on farms as small as 2–3 ha, a farm family has difficulty adequately controlling weeds by hand. A survey of Philippine farmers conducted by Institute economists showed that labour for weeding increased with adoption of high-yielding varieties. These analyses suggest that mechanical and chemical weed control is likely to increase output rather than displace labour, except in areas where wages are very low and farms are extremely small.

The recent success of Institute experiments in chemical weed control may bring a dramatic change in the weed control practices in tropical Asia. The 2,4-D results were most interesting. When applied 4 days after transplanting this low-cost herbicide adequately controls grasses, broadleaved weeds, and sedges. In the past, 2,4-D was known to effectively control only broadleaved weeds and annual sedges. The time of application is the key factor in control of grasses with 2,4-D. When applied after transplanting but before weeds emerge, it kills grasses as well as annual weeds. Institute agronomists recommend using 800 g (active ingredient) of 2,4-D to control weeds in 1 ha of paddy. The cost of treating 1 ha with the granular herbicide is only \$6, compared with \$12 for handweeding.

Weed control is more critical and more difficult in direct-seeded rice than in transplanted rice. When rice is direct-seeded, the weeds and rice emerge simultaneously and the weeds are highly competitive. Because the weeds cannot easily be distinguished from rice seedlings of the same age, labourers invariably damage the rice plants in direct-seeded rice. Experiments conducted by IRRI agronomists have shown that 1.5 kg/ha (active ingredient) of butachlor or of benthicarb applied 6–8 days after seeding successfully controls weeds in direct-seeded rice. The cost per hectare of either chemical is about the same as that of hiring labour to handweed transplanted rice.

Either of these chemicals applied at lower rates can also control weeds in transplanted rice. Weed control in upland rice is even more difficult than in direct-seeded rice. Butachlor in liquid form at 2 kg/ha active ingredient controls all annual weeds in upland rice.

This success of chemical weed control has stimulated the use of herbicides in the Philippines and other Asian countries. Because of a shortage of labour, or an unwillingness to control weeds by hand, the use of cheap herbicide is likely to become a widespread practice. Formulations and derivations of 2,4-D, MCPA, butachlor, and benthicarb are now being marketed in several countries.

Plant Protection

Warm temperatures and high humidity, which are typical of the tropical rice environment, are optimum for the development of organisms that are harmful to the rice plant. About 20 diseases and insects seriously damage the rice plant in the tropics; most are present in the Philippines. Institute scientists have concentrated their attention on the most widespread and damaging pests; these are blast, bacterial leaf blight, and tungro virus among the diseases and stem borers, plant-hoppers, and leafhoppers among the insects. Another major insect pest is the gall midge, which is not found in the Philippines. The Institute has also done considerable work on bacterial streak, sheath blight, and grassy stunt diseases and on the whorl maggot insect.

Improved management practices must include protection of the crop from diseases and insects. Chemical control of diseases has not been very successful in the tropics. Year-round rice cultivation favors rapid and frequent build-ups of pathogenic organisms that make chemical control uneconomical. The breeding of varieties resistant to diseases is the only practical method of disease control.

IRRI entomologists have evaluated hundreds of chemicals and have standardized their application methods for cheap insect control. Conventional foliar sprays and dusts do not penetrate dense foliage well and are easily washed off by rains. They must be applied

repeatedly for effective control. Early work at IRRI led to the standardization of paddy water application of insecticides in granular form. Granular insecticides are convenient for paddy water application and are far more effective because they function systematically in the plant. Two granular insecticides, lindane and diazinon, were found not only to be most effective in controlling insect pests of rice but also to be the least hazardous to man. Two applications of these chemicals controlled insects better than did 8–12 foliar sprays of such potent compounds as endrin and parathion. Carbofuran, which is also available in granular form, was identified as a highly promising insecticide in recent tests. Carbofuran controls all major insects when applied to paddy water, but it is relatively expensive.

The entomologists recently focussed their attention on developing new and less expensive methods of applying insecticides. In several experiments, placing insecticides 2 cm below the soil surface at 3 days after transplanting protected the crop from insects until harvest. The effect of insecticides is prolonged because they are less exposed to heat and sunlight and aerobic degradation, and are less susceptible to volatilization and loss in the paddy water. The insecticide applied in this manner is also expected to be less hazardous to the parasites and predators of rice pests. The insecticides were placed in protein gelatin capsules that dissolve in water. Two insecticide manufacturers also formulated cartap into tablets of the appropriate size and chlordimeform into large granules. These formulations had to be pushed below the soil surface by hand. Institute engineers are now working on the development of a mechanical applicator for placing such insecticides in the root zone.

In a series of experiments, root zone applications of carbofuran, cartap, and chlordimeform were compared with water application of carbofuran at 2 kg/ha active ingredient applied every 20 days, which is considered the most effective method of insect control (IRRI 1974). The root zone applications were as effective as the paddy water application of carbofuran, at only a fourth of the cost. Investigations have shown that a greater propor-

tion of insecticides is absorbed by the plant when it was applied to the root zone than when it was broadcast on the soil surface. For example, chlordimeform applied in the root zone was rapidly absorbed and translocated to the stems and leaves of the rice plants and its concentration in the plants was several times higher than that of surface application (IRRI 1974). Even 40 days after treatment the concentration of the insecticide applied to the root zone was twice as high as that applied to paddy water.

Rice Mechanization

Improved varieties and intensive cropping have increased the economic advantage and scope of rice mechanization. Farm surveys by Institute economists have shown that the new rice varieties have increased overall labour requirements. Reliable, low-cost sources of power are basic to the reorganization of small farms for increased production. In tropical Asia, a large portion of paddy land is medium-sized farms of 2–10 ha each. The Institute's agricultural engineering program is focussed primarily on the design and development of machines for such medium-sized farms, which are too large to work economically with animals, but not large enough to justify investments in large agricultural equipment imported from the industrialized countries. An integral part of the program is cooperation with agricultural equipment manufacturers to extend new machines to rice farmers.

Among the machines that the Institute has designed and released, the IRRI power tiller has made the greatest impact. The single-axle power tiller is simple and lightweight, and can be manufactured in most developing countries. It uses an imported 5- to 7-hp aircooled gasoline engine. The other tractor components are easy to fabricate locally in small shops. The number of companies that manufacture the IRRI-designed machine, or modifications of it, has increased rapidly. Since the design of the power tiller was released in 1972, 12 companies in the Philippines have received IRRI authorization to produce the machine. They are now manufacturing more than 500 tillers

per month. The IRRI-designed tiller costs about half as much as an imported tiller. Farmers like it because of its simple design, ease of maintenance, and low cost. The tiller has been tested in about a dozen countries; initial manufacture has begun in Sri Lanka, Thailand, and South Vietnam.

IRRI released its design for the axial flow thresher for commercial production in late 1973. Five Philippine companies are now building production models. Two companies in Pakistan, one in Sri Lanka, and one in South Vietnam have initiated prototype fabrication. The machine can consistently thresh and clean $\frac{3}{4}$ –1 ton of paddy per hour. It uses a 7-hp gasoline or kerosene engine. The engine of the power tiller is interchangeable; it can also be used on the thresher. The thresher can handle both dry and high moisture paddy efficiently.

Economical pumps are not available in the tropics for many low lift irrigation needs. A simple and low cost "bellows" pump was developed for this purpose at IRRI. It is designed for fabrication from light sheet metal, canvas, rubber, and wood, and can be built by small blacksmith shops. The pump is light and can easily be carried by one man. It can deliver 100–150 liters of water per minute and sells for approximately us \$25.

The design for the IRRI batch type drier was released for commercial production late in 1972. Since its release a number of changes have been incorporated into the design to improve its performance and to reduce cost. This 1-ton drier has an underlying plenum chamber through which heated air is driven upward into the grain mass. The bin can be made of either metal or wood. Its two parts are separated by a perforated metal sheet or a screened partition. Either a kerosene burner or a simple self-feeding rice hull furnace provides heated air. A ton of grain can normally be dried in 5–6 h. Five companies in the Philippines now produce the drier. Initial investment cost is about us \$550 with a metal bin, or \$350 with a wooden bin.

The multihopper seeder was designed to place pregerminated seeds in rows in lowland rice fields quickly and precisely. The machine

is made of sheet metal and meters out seeds by simple wooden rollers. The lightweight seeder can easily be transported across fields and levees. One man can seed 1 ha in 7–8 h with the machine. About 300 multihopper seeders were sold at approximately us \$50 each, in the Philippines during 1973.

Major Constraints to Production

Despite the development of high-yielding varieties and associated technology, the rate of adoption, as well as its impact on production is not as high as expected. Most farmers do not obtain yields in their fields as high as those demonstrated at experiment stations. The Institute is seeking explanations for these substantial yield differences.

The agricultural economics department participated in a cooperative regional project in which about 25 social scientists from different countries surveyed farms in 36 villages in 14 separate study areas in 6 countries during 1971–72 (IRRI 1974). The primary objective was to gather information on changes in production, income, and employment associated with the introduction of new rice technology, and on the major obstacles to further increases in rice production in these areas. Three major factors seem to explain many of the differences found among villages in the areas planted to high yielding varieties: (i) the availability of suitable varieties that combine high yield potential, with resistance to pests and good grain quality; (ii) the nature and quality of the rice-growing environment (solar radiation, water control, etc.); and (iii) the price relationships between improved and local varieties, and between rice and inputs such as fertilizer. Even in areas where adoption was widespread, the constraints to high yields most frequently mentioned were insects and diseases.

The Institute statisticians conducted experiments on farmers' fields in Laguna province, the Philippines, at four locations in the 1972 dry season, three locations on the 1972 wet season, and 14 locations in the 1973 wet season (IRRI 1974). All of these farms were within a radius of 25 km from the IRRI experiment station. Most farmers in Laguna prov-

ince are progressive and now use fertilizers and improved cultural practices. Factors such as insect control, water management, weed control, fertilizer, seed source, and seedling management were studied in each experiment at two levels—the farmers' levels (as practiced by the concerned farmers in the sample farms), and the recommended levels (the standard practices at the IRRI experiment station).

In the dry season, improved management practices increased yields in farmers' fields by an average of 85%. Absolute yield increases ranged from 2.4 to 4.4 t/ha. At one farm the yield increased to 9.6 t/ha with improved practices. Insect control, water management, and fertilizer were most crucial in raising rice yields in the dry season.

In the wet seasons, improved practices increased average yields far less: only 0.6 t/ha (14%) in 1972, and 1.3 t/ha (63%) in 1973. Insect control was by far the most important factor contributing to yield; it accounted for more than two-thirds of the yield differences between recommended and farmers' practices. Weed control ranked second. Most farmers in the study area were already using adequate fertilizer.

The new rice technology has proved highly profitable in areas where solar radiation is high and irrigation water is adequate. For example, national yields in Pakistan increased by 50% during the 3-year period ending in 1969–70 with the adoption of modern varieties on a third of its rice area (Athwal 1971). Rice is grown in Pakistan under irrigated conditions with extremely low rainfall and high solar radiation. Modern varieties give high yields in other countries when grown during the dry season with adequate irrigation. But the existing technology is less suited to unfavourable environments, such as wet season, poor water control, low solar radiation, and high incidences of diseases and insects.

A recent Institute study in the Philippines clearly shows that poor management practices, as well as poor environments, markedly limit farm yields (IRRI 1974). To realize the full yield potential and to maximize benefits from the new technology, all factors which con-

tribute to production must be optimized. For example, the data collected by Institute economists both in the Philippines (R. Barker, unpublished) and Thailand (IRRI 1973) emphasized the high degree of complementarity between weed control and fertilizer input for obtaining high yields and income. High levels of either one increased yield and income insignificantly. Marked increases in yields and farm income levels came only with heavy applications of fertilizer accompanied by good weed control.

Overcoming Production Constraints through Genetic Improvement

On the basis of research information now available, it appears that several of the constraints to production can be removed or at least their adverse effect minimized through genetic improvement. Perhaps water and fertilizer are the most important inputs for increasing rice yields. Inadequate water supplies, or excesses of water, limit the potential yields in some areas. After water, the most important factors that limit yields are insects, diseases, and weeds. Adverse soil conditions that affect lowland rice include salinity, alkalinity, zinc deficiency, and iron toxicity. Aluminum toxicity and iron deficiency interfere with the response of new varieties to fertilizer and other inputs in upland rice. Low temperatures prevail in many rice areas at high altitudes and in northern latitudes. An enormous potential exists for incorporating built-in resistance or tolerance to insects, diseases, drought, deep water, low temperatures, and adverse soil conditions.

IRRI maintains a "germ plasm bank," or collection of more than 25,000 varieties. Scientists have screened these varieties and identified sources of resistance or tolerance to these yield-limiting factors. Genetic materials that are almost immune to different diseases and insects are available. Some varieties in the germ plasm bank have resistance to salinity, alkalinity, or iron toxicity. The traditional varieties that are grown in areas of deep water can elongate several meters as the water rises. Studies have established that the genes responsible for elongation can be combined with

the semi-dwarf plant type. Varieties may be developed that remain short under normal conditions, but that have the capacity to elongate as the water deepens. Other rices have been identified that are tolerant to drought and low temperatures.

Small-scale tropical farmers generally are not willing to take risks and are hesitant to invest in inputs. For example, farm surveys by Institute economists have shown that although farmers have increased insecticide use over the past few years, they still generally apply only low amounts. The normal farm practice is to use the chemical when damage is visible. The insect damage varies with location, season, and variety. Although it is difficult to rely on chemicals as a major insect and disease control measure, farmers quickly identify and adopt resistant varieties. Modern varieties must obviously be improved to provide genetic protection against unfavourable conditions in order to lower the costs and reduce the risks of producing high yields.

Institute scientists have made remarkable progress, through intensive cross-breeding, in transferring disease and insect resistance from different sources into improved genetic lines. Fig. 3 shows that 70% of the selections included in the 1973 replicated yield trials were resistant to at least five major diseases and insects (IRRI 1974). Only 4 years ago, less than 15% of the entries in these trials were resistant to two pest organisms, and none were resistant to three pests. Some of the experimental selections now being tested have combined resistance to blast, bacterial leaf blight, tungro virus, grassy stunt virus, green leafhoppers, brown planthoppers, white back planthoppers, and stem borers (Table 2).

The new crosses that are now being studied are designed to incorporate resistance or tolerance, not only to diseases and insects, but also to other unfavourable environmental factors, into lines that yield well and have good grain quality. The genetic recombination of all these characters into single varieties requires a massive breeding program. The Institute has expanded and accelerated its breeding program and now makes about 2000 crosses per year, compared with only 200–300 crosses in the

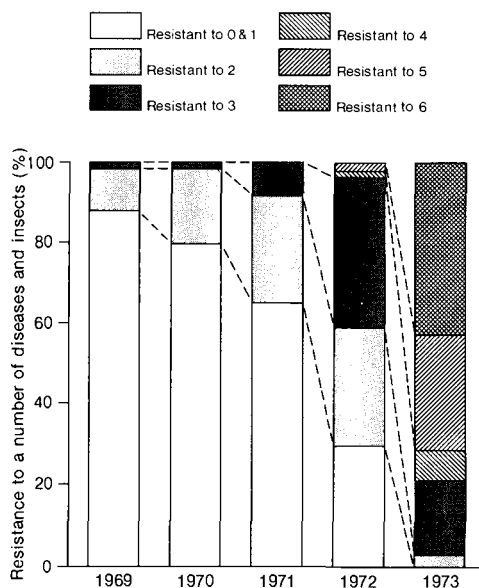


FIG. 3. Proportion of entries in replicated yield trials with multiple resistance to important diseases and insects (blast, bacterial blight, tungro, grassy stunt, brown planthopper, and green leafhopper). Each year's trials consisted of about 185 entries.

past. The development of varieties suited to unfavourable environments is a long range program that offers a continuing challenge to rice breeders. Diseases and insects have the capacity to change and new varieties must continuously be bred to withstand these variations.

Research Utilization

The Institute orients its activities to insure that the new information and materials generated by its research are shared with national rice programs. The genetic material developed by IRRI is available to every rice-growing country for evaluation and ultimate use as varieties. IRRI has a large training program and provides about 80 man-years of training to young scientists every year. During their stay at IRRI, the scholars are encouraged to work on problems that are important in their countries. Many of the scholars take selected genetic lines from the breeding materials back with them for evaluation at their home stations. IRRI publications are distributed to the major rice research stations and libraries

TABLE 2. Reactions of named varieties and promising selections to major diseases and insects.

Variety/ selection	Blast	Bacterial blight	Bacterial streak	Tungro	Grassy stunt	Green leaf- hopper	Brown plant- hopper	White back plant- hopper	Stem borer
IR8	MR ^a	S	S	S	S	R	S	S	MS
IR26	MR	R	MR	R	MR	R	R	S	MR
IR2061-464-2	R	R	MR	R	R	R	R	S	MR
IR2071-88-10	R	R	MR	R	R	R	R	R	MR

^aR, resistant; MR, moderately resistant; S, susceptible.

around the world. For example, the Institute sends its annual research report to about 2000 addresses, mostly rice researchers in the less developed nations. The *IRRI Reporter*, a bi-monthly publication, goes to 4000 addresses, mostly scientists, extension workers, teachers, and farmers.

We recognize that most of the work for increasing rice production in any nation must be carried out by research stations of that nation. Strong national institutions are essential prerequisites to accelerated progress. The Institute is engaged in cooperative projects in the major rice-growing countries to help them improve their research capabilities. Projects in India and Pakistan have been completed; each lasted for more than 5 years. Cooperative country projects in Bangladesh, Indonesia, Sri Lanka, Vietnam, Egypt, and the Philippines are continuing.

Three parties are usually involved in the development of a cooperative country project — the national agency, IRRI, and an agency that is willing to finance IRRI's participation. A project normally provides for assignment of one or more IRRI scientists and short-term consultants, training for local scientists, and supply of essential equipment. Institute scientists employed in country projects work as members of local teams on local problems. These projects are in no way intended to be branch stations of IRRI. Not only are technical resources of the project applied to enhance the local research efforts, but also the Institute at Los Baños often incorporates into its research program supplementary investigations to help solve rice production problems in the

host country. The Institute emphasizes that its efforts in a country must be a part of the national program. IRRI has also stimulated the development of coordinated national programs where they did not previously exist.

Inadequate extension programs may limit the adoption of improved technology and the achievement of production goals in some countries. Although IRRI's major focus is on research and the training of research scientists, IRRI also trains extension workers, co-operates in adaptive research on farmers' fields, and helps develop new extension techniques. The Institute has assisted some countries in accelerating the adoption of improved technology. Working cooperatively with Philippine agencies, IRRI developed the concept of "Rice minikits" to accelerate the dissemination of new varieties among farmers. Each minikit contains seeds of several new selections, fertilizers, insecticides, and herbicides to plant small plots on farmers' fields. The technique is designed for large-scale evaluation of selections prior to their release under a range of environments and to give farmers an opportunity to choose the selection that gives best performance under farm conditions. In addition to the Philippines, the rice minikit has proved a powerful extension tool for disseminating the new varieties in Sri Lanka and India.

More recently, IRRI scientists working with local Philippine agencies have developed an extension methodology that can be applied in other countries. The methodology includes the use of a "package" of practices (improved varieties, proper use of inputs, etc.), a mass

informational campaign, farmers' field days, training of technicians, improving the mobility of technicians, assuring an adequate supply of inputs, and timely credit. Through its cooperative projects, IRRI will stimulate the use of this methodology in other countries, and will continue to help demonstrate the effectiveness of new technology in increasing rice yields at the farm level and in improving the living conditions of farmers.

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Improvement of Crops and their Relationship to Nutrition and Food Science Technology in the Semi-Arid Tropics

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Abstract In the semi-arid tropics water and not land is the limiting factor in crop production. The dry season lasts between 5 and 10 months. Sorghum, pearl millet, pigeon pea and chickpea are the most important cereal and pulse crops of the region. Low yields, instability of production, low nutritional quality of the existing varieties, and high disease and pest susceptibility are the serious problems. The International Crops Research Institute for the Semi-Arid Tropics seeks solutions to these problems particularly in increasing yield and stabilizing production under rain-fed conditions of the semi-arid tropics. Interdisciplinary research programs of biological scientists, physical scientists, engineers, nutritionists, and economists have been started. Important steps toward these goals include: collection, evaluation, and utilization of the world's resources of germ plasm collected from many sources; development of varieties of composites or hybrids with high yield potential, disease resistance, high lysine, and high protein efficiency ratio; screening and evaluation of varieties and promising lines for high nutritional value; improvement in drought tolerance and environmental screening and stability characteristics of the variety; and development of plant morphology to make the varieties suitable for intercropping, companion cropping, and relay cropping.

Résumé C'est l'eau et non la terre qui constitue le principal facteur limitant la production agricole dans les régions tropicales semi-arides. Le sorgho, le mil à chandelles, le pois cajan et le pois chiche constituent les céréales et les légumineuses principales de cette région, dont elles servent à mesurer la productivité. La saison sèche dure de 5 à 10 mois. La faiblesse des rendements, l'instabilité de la production, la faible valeur nutritive des variétés cultivées, ainsi que la grande sensibilité de celles-ci aux maladies et aux parasites constituent autant de problèmes sérieux. L'Institut International de Recherches sur les Cultures dans les Régions Tropicales Semi-Arides se penche sur les solutions à apporter à ces difficultés, notamment sur celles de l'accroissement des rendements et de la stabilisation de la production dans les conditions de culture pluviale qui sont celles de ces régions tropicales semi-arides. Il a mis en oeuvre des programmes de recherches interdisciplinaires auxquels participent des biologistes, des physiciens, des techniciens, des nutritionnistes et des économistes. La poursuite des objectifs prévus comporte les étapes suivantes: Rassemblement, évaluation et utilisation du matériel génétique provenant de nombreuses

sources réparties à travers le monde entier; création de variétés d'hybrides à potentiel de production élevé, résistants aux maladies, à forte teneur en lysine et dotés d'un fort coefficient d'efficacité protéique; sélection et évaluation de variétés et de lignées prometteuses du fait de leur haute valeur nutritive; amélioration de la résistance à la sécheresse, de l'adaptabilité et de la stabilité de ces variétés; obtention de variétés dont la morphologie convienne à la culture en intercalaire, à la culture mixte et aux cultures d'appoint.

THE problem of food shortage and malnutrition is becoming more acute as the population increases. The problem is most acute in Africa, Asia, and Latin America, particularly in the arid and semi-arid regions. It is aggravated during droughts and aberrant weather, which affect the success of food crops. There is considerable scope for increasing production of food crops in the tropics.

The staple cereal diet in the semi-arid tropics consists of sorghum and millets, and the main source of protein is the grain legumes, particularly pigeon pea and chickpea. This is certainly true in the semi-arid tropics of Africa and the Far East, particularly India. FAO statistics for 1972 (Table 1) show 49 and 34% of the area under cereals is devoted to cultivation of sorghum and millets in Africa and India, respectively. The major areas of the world under pigeon pea and chickpea cultivation is also in India: where 90% of the world's area under pigeon pea and 76% under chickpea. Though the area under these crops is fairly high, the yields are very low (Table 1).

Out of a total production of 23.4 million tons of sorghum (produced as human food grains) in the developing countries, 33% comes from India and 37% from Africa. The sorghums and millets provide not only the calories but also about 70% of the protein for the population. The balance of protein needs is provided mostly by grain legumes. In food grain legumes, 97% of chickpea and 96.4% of pigeon pea are provided by the developing countries. The edible grain legumes have exceptional potential for alleviating the malnutrition in the tropics because of their wide adaptation, low fertilizer requirements, multiple and high quality of protein.

When we consider that 38% of the world's population lives in the tropics and Southeast Asia including India, it is clear that to meet the food needs of the world sorghum, millets,

pigeon pea and chickpea are most important crops. ICRISAT is therefore concentrating its efforts on these species, with pressing demands to study groundnuts since they also represent an important source of protein in the semi-arid regions of the world.

Troll's classification is used to define semi-arid regions: 5–10 arid dry months, and 2–7 humid months with erratic distribution of rain. In certain areas of this region sorghum and millets occupy a favourable competitive position in the present food production system primarily due to distribution and amount of precipitation and evapotranspiration patterns. On the basis of these criteria of climate and crops the semi-arid and tropical region comprises a 400–900 km wide strip across Thailand, Burma, India and Pakistan, a 900 km wide belt across Africa from Senegal to Kenya, a 1300 km wide belt from Angola to southern Tanzania. Scattered areas from northeast Brazil to central Mexico, northern Argentina and northern Australia also fall in this category. Generally the region has 500 to 1500 mm of rainfall. Brief droughts may often occur during the monsoon season making agriculture unstable and frequently unproductive.

Problems

The main problems of crop production in the region are the following: (1) long dry periods alternating with short wet periods of low rainfall; (2) erratic distribution of rainfall with occasional occurrence of droughty periods; (3) occurrence of black, red, and sandy soils, which offer numerous problems of soil and water management; (4) predominance of rainfed agriculture due to inadequate supply of available water for irrigation; (5) low yields of sorghum, millets, and grain leg-

TABLE 1. Area, production, and yield of sorghum, millets, pigeon pea, and chickpea in different regions of the world, 1972.

Region	Total under cereals	Millets	Sorghum	Total of sorghum & millets expressed as % of total under cereals in the region	Pigeon pea	Chickpea	Total of pigeon pea & chickpea expressed as % of total under food legumes in the region
1	2	3	4	5	6	7	8
(A) Area under the crop (million ha)							
World	699	65.00	39.9	15.0	2.587	10.54	23.7
<i>Developing countries</i>							
Africa ^a	54	13.80	10.3	44.0	0.147	0.50	6.3
Latin America	46	0.40	2.8	7.0	0.050	0.23	4.0
Near East	36	0.99	3.5	12.0	—	0.26	2.0
Far East ^b	152	17.60	16.6	22.0	2.390	9.23	43.0
India	96	16.50	16.0	34.0	2.310	8.00	48.6
Centrally planned	263	32.20	0.11	12.2	—	—	—
(B) Production (million tons)							
World	1275	43.0	46.7	7.0	1.72	6.72	19.7
<i>Developing countries</i>							
Africa ^a	46	8.5	7.5	35.0	0.07	0.35	7.1
Latin America	67	0.33	5.0	8.0	0.041	0.20	5.1
Near East	48	1.4	3.3	9.8	—	0.28	15.3
Far East ^b	206	8.2	7.6	7.6	1.61	5.70	59.7
India	107	7.6	7.2	14.0	1.57	5.10	62.6
Centrally planned	4560	24.5	0.13	5.0	—	—	—
(C) Average yield per hectare (kg)							
World		600	1170		665	627	
<i>Developing countries</i>							
Africa ^a		612	733		483	612	
Latin America		815	1735		324	804	
Near East		1434	945		—	1000	
Far East ^b		464	460		673	625	
India		461	450		681	636	
Centrally planned		761	1099				

Source: FAO Production Year Book, Vol. 26, 1972.

^aAfrica excluding South Africa.

^bFar East includes India.

umes, which form the main food of the people; (6) poor and unbalanced human diet due to inadequacy of proteins and deficiency

of certain amino acids like lysine, methionine, cystine, etc.; (7) inadequate agricultural research base in the region.

ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was set up in July 1972 with international financial support. ICRISAT focuses attention on the development of technology for increasing production and increasing nutritional quality of sorghum, pearl millet, chickpea and pigeon pea for cultivation under rain-fed conditions in the semi-arid tropics. Groundnuts may be included in its research program since it is one of the important crops and fits into the cropping system. One of the most important responsibilities of ICRISAT is to develop farming systems which will help to increase and stabilize agricultural production by optimizing the use of natural and human resources. To meet these objectives, ICRISAT must develop training and outreach programs throughout the semi-arid regions. Steps have already been taken to identify suitable centres for outreach activities in Africa and Latin America.

Sorghum & Millets

Sorghum and millets are the most widespread cereal crops grown in the semi-arid tropics. Pearl millet is the most dominant crop grown in comparatively drier conditions on lighter soils. Sorghum is preferred on heavier soils having a higher moisture retention capacity.

In the last decade great strides have been made in the improvement of grain sorghum. In the developed countries sorghum is produced for animal feed and yields are high; yields produced for human food are low. In countries like India, a number of hybrids which yield 2–5 tons/ha under rain-fed conditions and proper management of soil and water have been introduced but still there is no breakthrough in production. The most serious problems are inadequate adaptability and higher susceptibility of the varieties or hybrids to diseases and pests; poor keeping-quality of the grain; lower acceptability of the grain and flour; high cost and unsatisfactory supply of hybrid seed; and unavailability of better varieties and hybrids for the dry season.

The International Symposium on Sorghum in the 1970s held in India highlighted these aspects and discussed the approaches for research on these problems. The research work undertaken at ICRISAT is attempting to overcome these defects and develop varieties or hybrids suited to different environmental conditions. Development of varieties and resistant to important diseases like smut, downy mildew, and blight, and pests like sorghum shootfly, stem-borer, and midge will bring about a revolution in sorghum production. We still do not know the desirable morphology of an efficient sorghum plant. Grain sorghum occupies a prominent place in the food of the poor peoples in developing countries, and it occupies the fourth place in the cereal foods of the world but first in the semi-arid tropics. However its nutritional quality is not very good, and consumption of large quantities may cause malnutrition-related diseases in man. According to Gopalan and Srikantia (1960) the presence of a relatively high concentration of leucine and/or imbalance of leucine:isoleucine ratio in sorghum is responsible for pellagra in a population subsisting on sorghum.

It is, however, realized that the acceptable quality of grain is a very important characteristic. The plant breeders are very conscious of the necessity of upgrading the quality of the grain. A worldwide search is being made for a germ plasm possessing disease and pest resistance and better grain quality. An outstanding discovery has been made by the Purdue University group in locating two high-protein and high-lysine varieties of sorghum from Ethiopia. Rameshwar Sing and John Axtell (1973) analyzed these varieties locally called *Marchuke* (IS 11167) and *Wetet-Begunche* (IS 11758). The former in local Ethiopian language means “honey spurts out” and the latter denotes “milk in the mouth.” *Marchuke* is grown at higher elevations. The main characteristics of these varieties are high protein, high lysine, and high oil and fat and low tannin content (Table 2).

Singh and Axtell have also reported that high lysine gene alters the amino acid pattern in hl. hl. hl. endosperm tissue in relation to normal endosperm checks. The major changes



Evaluating sorghum germ plasm.

are increased lysine, arginine, aspartic acid, glycine and tryptophan and decreased content of glutamic acid, proline, and leucine compared to normal endosperm tissue.

The farmers in Ethiopia have been growing these varieties for centuries, not as pure crops but as an admixture with the normal sorghum varieties which give higher yields than the

special purpose or novelty varieties. The farmers start harvesting them at milk ripe stage and eat the roasted grain. When the crop is fully ripe some of the grain of the varieties is also harvested along with the rest and reprocessed together. These varieties offer a great promise for upgrading the nutritional quality of sorghum, but it is not envisioned that they

TABLE 2. Main characteristics of Marchuke and Wetet-Begunche.

Character	High lysine lines		Normal sorghum
	IS 11167 (Marchuke)	IS 11758 (Wetet-Begunche)	
Protein (%)	15.70	17.20	12.70
Lysine (g/100 g. protein) in proteins	3.33	3.13	2.05
Lysine % in sample	0.524	0.540	0.258
Oil %	5.81	6.61	3.32
Sucrose %	3.08	2.61	1.03
Catachin equivalent (Tannin)	0.34	0.37	0.38

*Data courtesy of Rameshwar Singh and John Axtell

can replace the normal varieties of high yield potential. Axtell and his associates have observed that as compared to normal sorghums the high lysine lines gave nearly 2 to 3 times more grain in weight of weanling rats. Thus there are great prospects of upgrading the nutritive value of the sorghum through the newly discovered varieties. They are also excellent sources of special foods including baby foods, and offer a means of upgrading the cereal/pulse diet particularly for the poor sections of the population. ICRISAT is making use of this germ plasm in evolving higher-yielding and nutritionally superior varieties through genetic engineering. Purdue University is doing pioneering work on this problem and ICRISAT is collaborating with them.

Upgrading the quality of protein and lysine content in sorghum is one of the methods of improving the nutrition of the poor people, but balancing the diet by supplementation with grain legumes or pulses of high quality is another. The fall in production of pulses and resulting high price further aggravated the protein- and lysine-deficiency diseases. Thus, while the emphasis for better protein and high lysine varieties will be very useful, more rewarding results may be achieved by increasing the yield potential of pulses, and their nutritive value, since they are conventional supplements for cereals particularly in countries like India. ICRISAT scientists are continuing to emphasize improvement of sorghum yield potential consistent with quality, and do not wish to sacrifice yield at the cost of quality. We are more interested in harvesting markedly larger amounts of calories, proteins, and amino acids per hectare than per 100 grain weight.

It is well known that deficiency of plant nutrients not only depresses yield but also lowers quality of the produce. The role of nitrogen, phosphorus, and potassium in this case is also well known but the significant part played by micronutrients like zinc, iron, copper, etc. is not so well appreciated. Indian experience with wheat, rice, sorghum, and chickpea has shown that in a zinc-deficient soil not only the protein content in the grain falls but the lysine content also decreases. The

sulphur deficiency likewise causes reduction in sulphur-containing amino acids such as methionine and cystine. Future work at ICRISAT will examine this problem more intensively. Proper nutrition of the plant may solve many of the malnutrition problems.

Under the UNDP Programme on Sorghum and Millets at ICRISAT, an effort will be made to assess the nutritive quality of various varieties in addition to crop improvement. Thus the world germ plasm will be completely analyzed and nutritive value assessed. We plan to analyze about 8000–10,000 samples every year. We feel that there is some germ plasm in inaccessible areas of India, mountain areas of Ethiopia, and other areas of Africa where good germ plasm with some special features may be available. A survey might yield very valuable results.

One other aspect which needs attention is the post-harvest technology of coarse grains like sorghum and millets. These cereals have a low commercial value and have not attracted much attention from the technologists. Moreover, in the developed world they are primarily used as animal feed and not as human food, thus the processing technology is not well developed. However, some work has been done at the Central Food Technological Research Institute, Mysore, showing that by suitable processing excellent tasting products can be made, which may have much appeal even to the developed world. The possibility of extracting oil from varieties with high protein, high lysine, and high fat seems to be very good. In Ethiopia some firms are already considering this possibility for the manufacture of high protein animal feeds after extracting fat and oil from these varieties. In view of the worldwide shortage of vegetable oil this is a promising development. Dr. Hugh Doggett and his group at ICRISAT have assembled about 18,000 lines of the world germ plasm and the elite material from major centres of research in sorghum. They are evaluating and using the germ plasm in an extensive breeding program. The main aim is to develop genetic material which could be useful for plant breeders in different countries for developing

varieties and achieving a breakthrough in sorghum production.

Millets

Millets constitute the most important crop of the semi-arid tropics, particularly in the developing countries. Pearl millet is the most important crop. India has the largest area (10 million ha) under this crop in the world. Other important millet-growing countries are Nigeria, Niger, Mali, Chad, and Senegal. Pearl millet, which originated in Africa, forms the poor man's diet and is grown mostly on sandy loam soils and under arid climates. The development of high-yielding hybrids in the last decade has been really a major breakthrough in this crop. The major thrust at ICRISAT on this crop is on the development of hybrids with high-yield potential, downy mildew resistance, and better nutritive quality. Another problem is infection with ergot. This crop, because of its shorter duration, low water requirements and rationing ability, has great potential in the whole of this region. In India, which has nearly 60% of the entire area under pearl millet in the world, next to wheat, there has been a revolution in the production of this crop as a result of introduction of hybrids. At present five hybrids are being cultivated but most of them have succumbed to downy mildew and ergot, which are the biggest menace. Since the susceptibility to these diseases is being contributed by the common male sterile line 23A, an intensive search is under way for disease-resistant male sterile lines, and some have already been identified. We feel that composites and synthetics may have a better chance of succeeding against new races of diseases than hybrids. Our efforts are therefore being directed toward developing varieties as well as hybrids. Three crops of pearl millet can be grown at Hyderabad in a year, which will greatly accelerate the breeding program. At present our germ plasm resources are deficient in African material. A vigorous collection program is planned to make up for this deficiency.

Intensive work on upgrading the quality of pearl millet is under way. In the world germ plasm collection there are some lines with

21% protein compared to 6–8% in normal lines. Efforts are being made to increase the protein content moderately and improve its quality by raising lysine content consistent with high-yield potential. Pearl millet has a high fat content hence high caloric value. However, efforts are to be made to improve its digestibility.

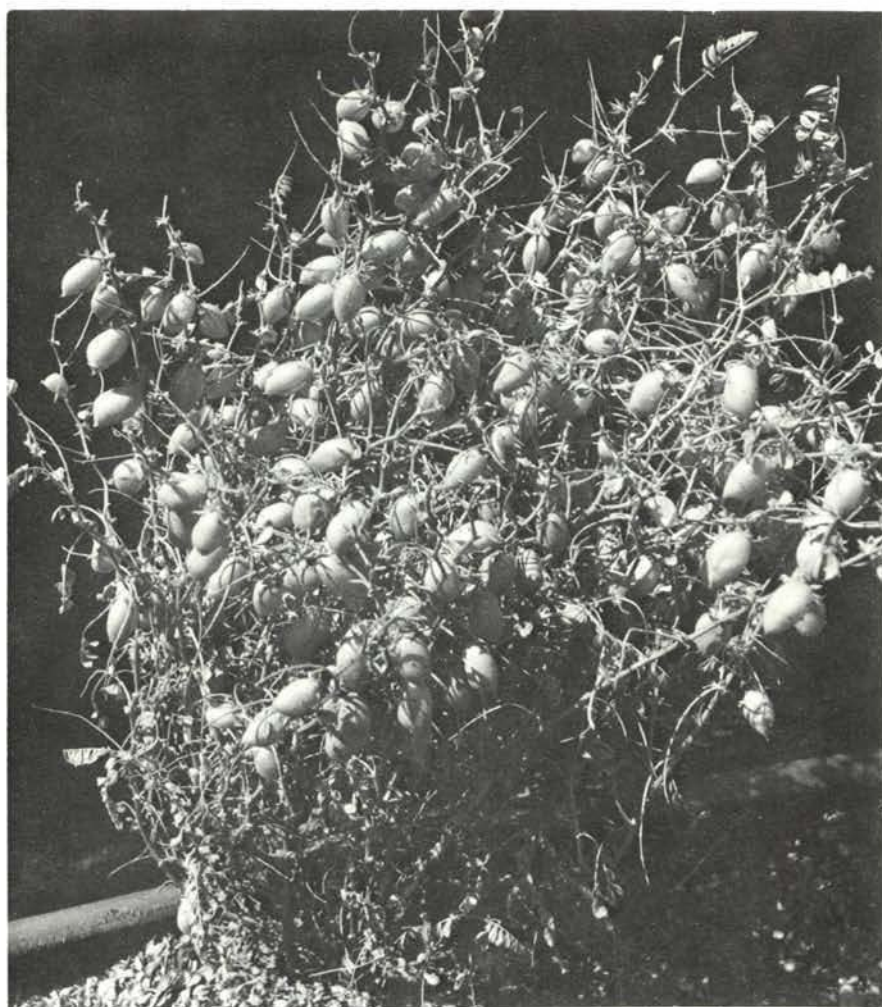
Very little work has been done on nutritional quality and amino acids content in the pearl millet lines. In 1974, we hope to chemically analyze and screen for nutritive quality the world germ plasm which at present consists of 2700 lines.

The technology of processing pearl millet needs further study. Preliminary investigations in the CFTRI at Mysore show that the grain can be processed and many crispy products made from it. It is also a good source of fat which can be profitably extracted. This grain crop has tremendous potential which has yet to be exploited.

Researchers at ICRISAT are developing not only hybrids of high-yield potential and disease resistance but also the composites of different maturity groups. They have identified four maturity groups: (1) early maturity composites (EC), 45 days to heading; (2) medium maturity composites (MC), 45–55 days to heading; (3) late maturity composites (LC), 55 days to heading; and (4) dwarf maturity composites (DC).

Chickpea and Pigeon Pea

The food legumes are the major source of protein and other nutrients in the diet of most people in the semi-arid tropics, and in fact in all the developing countries. Recent statistics show that Southeast Asia, particularly India, and Africa are the main suppliers of these vegetable sources of proteins. Of the food legumes, groundnut contributes 36%, chickpea 16%, and pigeon pea 6.9% to the total production in the tropics. These crops also occupy an important position in cropping patterns, crop rotation, and mixed cropping systems. They represent the most neglected crops and are often grown on marginal soils without much care. Very little research has been done on improving yield potential and nutritional



An elite chickpea variety.

quality. They are rich sources of protein and lysine but not methionine and cystine. They are high in calories (350–570 cal/100 g edible protein) and are good sources of thiamine, nicotinic acid, tocopherol, calcium, iron, and phosphorus. Because of the serious shortage of proteins in the world, and the dominance of chickpea and pigeon pea in the pulses group in the developing countries, ICRISAT has selected these crops for plant improvement research. The distribution of these crops in the top seven countries having the largest area under the crop is given in Table 3.

India has 90% of the world acreage and 91% of the world production of pigeon pea

(Table 3), and 76% of the world acreage and 91% of the production of chickpea. The second biggest contributor to both these crops is the African region.

The consumption of chickpea and pigeon pea per day in important pulse-consuming countries is as follows (FAO statistics):

Chickpea	Grams/day	Pigeon Pea	Grams/day
Mauritania	23.7	Dominican Republic	14.9
India	20.4	India	8.2
Togo	20.1	Burma	1.6
Ethiopia	16.7	Uganda	5.0
Jordan	6.6	Malawi	3.5

TABLE 3. Distribution of chickpea and pigeon pea.

Region	Area (thousand hectares)	Yield (kg/ha)	Production (thousand hectares)
Chickpea			
India	8027 (76%)	636	5106 (76%)
Pakistan	970	532	516
Ethiopia	302	642	194
Mexico	215	837	180
Spain	145	560	62
Turkey	115	1478	170
Iran	100	500	50
World	1054 (100)	637	6718 (100)
Pigeon Pea			
India	2311 (90%)	681	1574 (91%)
Uganda	90	444	40
Burma	74	405	30
Malawi	35	571	20
Dominican Republic	27	1000	27
Tanzania	22	500	11
Venezuela	11	509	6
World	2587 (100)	665	1720 (100)

FAO also reported that the consumption of pulses has fallen from 75 to 39 g/day due to inadequate supply and high price. This is causing great concern. To make a breakthrough in legume crops all the diverse germ plasm available in the world should be used. At present, ICRISAT has a collection of nearly 8000 lines in pigeon pea and 7562 in chickpea. The collection from Africa and Latin America is extremely inadequate. All the available germ plasm from these countries should be quickly collected and used for developing high-yielding and nutritionally superior varieties. Unlike sorghum and pearl millet whose second and third generations respectively can be taken in a year at Hyderabad, pigeon pea and chickpea is successfully grown only once a year. The question of taking the second generation for expediting the breeding program is very important. In case of chickpea there is a possibility of taking second generation in Lahaul Valley in Himachal Pradesh at an altitude of 10,000–12,000 feet above sea level. The other possibility is in the Middle East (e.g. Lebanon, Iran, Tur-

key, etc.), but virus diseases may create plant quarantine problems. We are exploring these possibilities to give us two generations of chickpea in a year.

We are also trying to raise the second generation of pigeon pea under irrigation at Hyderabad.

Major Problems in Improvement of Chickpea and Pigeon Pea

Low Yield Potential

The existing varieties have low yield potential although pigeon pea yields 10–25 q/ha under unirrigated conditions and 40–50 q/ha under irrigated conditions (Ramanujam 1973). Chickpea breeding trials in India have yielded 25–35 q/ha. Even from large-scale trials, chickpea yields of 20–30 q/ha are common. The first objective of the ICRISAT research programs is to improve productivity. Changing the plant architecture genetically and increasing harvest index is the foremost problem. The second objective is the yield stabilization by improving adaptability of the varieties to various environmental extremes.

Resistance to Diseases and Pests

Another ICRISAT objective is to produce disease-resistant varieties. The most serious fungal diseases of chickpea are wilt and blight and in pigeon pea wilt and others. In some countries even viral diseases affect these crops. The pod borer is a serious pest of both crops and reduces yield considerably.

Nutritional Problems

Unlike cereals, so far no food legume varieties have been developed which would be highly responsive to fertilizers, particularly phosphates to which the legumes generally respond. Unless some significant results are achieved, large increases in yield per hectare will not be possible. The nitrogen metabolism in food legumes is not well understood, although at the time of pod filling the nitrogen level in leaves and stems falls to such a low



Comparative study of pearl millet genetic material.

level that the grain formation is seriously affected. Many plant physiologists feel that at this critical stage nitrogen may be a limiting factor. This area requires further investigation. Specific susceptibility to zinc and other micronutrients also needs investigation. Indian experience suggests significant varietal differences.

Genetic improvement of nutrient composition and digestibility

Protein:

Generally both chickpea and pigeon pea have 18–21% protein and there is a good opportunity to increase this level as well as the quality of protein. The higher yield potential

should be measured not in terms of dry grain weight but in terms of amount of protein produced per hectare, and its quality.

Amino Acid:

Methionine and cystine are generally the limiting amino acids in the food legumes except for pigeon pea in which tryptophan is also limiting. Thus a concerted effort is necessary to improve the content of these amino acids. Improving sulphur nitrogen and phosphorus content of the grain should help in improving the content of these sulphur-bearing amino acids. Some observations in India show that in the chickpea varieties generally there is an inverse relationship between sulphur content and methionine content, whereas



Evaluating a variety of pigeon pea.

in *Vigna mungo* and *Vigna radiata* application of sulphur increases the methionine content. Very recent studies using radiation techniques have shown that in soils deficient in sulphur, chickpeas also respond similarly to *Vigna Mungo*. More basic studies are needed to understand the problem.

Stepping-up protein content:

Since food legumes are used to supplement cereal foods (which generally have a low lysine content), the lysine content in legumes should be increased to compensate for the deficiency in cereals. Other essential amino acids like threonine, if they become limiting factors in the overall diet, need to be increased in the food legumes to balance the cereal diets. More research is necessary to determine the extent to which the amino acid content can be modified in plants.

The Protein Advisory Group of the UN suggests that certain minerals (zinc, calcium, cerium) and vitamins in the legume grains

should also be maintained at the highest possible level. Improvement of productivity, adaptability, and yield stability should be the first priority. Improving the nutritional value of legumes and reducing the concentration of some undesirable constituents (flatulence-producing feature of the chickpea could be lessened by genetic engineering), is next in importance.

Plant type for special purpose

In many countries, particularly in Latin America, Kenya, and Bangladesh, green pods of pigeon peas are used for canning or vegetable purposes. Thus while an effort has to be made for high-yielding and dry, grain-producing varieties the special requirement for canning and vegetable purposes also needs to be met.

Pigeon pea is also well suited for mixed cropping and relay-cropping systems. The

plant type and its maturity durations are the most important factors for this purpose.

In India, pigeon pea is generally grown as an intercrop with cereals, particularly sorghum. The varieties in use are generally slow-growing initially and are of long duration (8–9 months). So even with a normal spacing of sorghum and intercropping of pigeon pea, which is often broadcast, the yield of the main crop is not greatly affected. However, pigeon pea does not make normal growth till sorghum is harvested. At ICRIASAT, experiments are under way to select types of sorghum, pearl millet, and of pigeon pea which will make ideal combinations for intercropping or companion cropping. Pattern of cropping is also being studied. Paired-row system, compressed rows, and a regular pattern of 3–4 solid rows of the cereal crop with one row of pigeon pea are also being studied. The short plant type with erect growth habits seems promising. Of the cereals, pearl millet may be even more promising than sorghum for companion cropping.

Possibilities of companion cropping of sorghum and pearl millet with soyabean, mung bean (*Vigna radiata*), and relay cropping with chickpea, safflower, and setaria, are also being examined. Plant morphology and length of growing season of the main cereal and of companion or relay crop is very important. Critical plant population beyond which the yield of cereal declines, or the maximum population of the intercrop of the same maturity as the main crop, is very important as it affects the efficient utilization of arable land.

In north India a short-duration variety (120 days) would be ideal for rotation with wheat. Thus the past tradition of cultivating slow-growing and long-duration varieties has to be replaced with shorter-duration but higher-yielding varieties. The germ plasm obtained from Brazil may have high potential for breeding such varieties. Chickpea germ plasm from Ethiopia, the Middle East, and Mexico may be very useful as well for cross-breeding programs.

ICRIASAT is making considerable effort to collect germ plasm from all sources. We are collaborating with ALAD in Beirut, US

Program in Puerto Rico, and All India Coordinated Pulse Program in India. Detailed knowledge concerning the genetic, chemical, and nutritional characteristics of these germ plasms will speed up the realization of our objective of developing higher-yielding varieties with better nutritional quality, particularly higher lysine and methionine content.

Rhizobial cultures for grain legumes

Grain legumes are credited with nitrogen fixation, but very little is known regarding the varietal differences. The rhizobial culture for chickpea and pigeon pea have not produced any spectacular results. It is essential to make a basic study of the varietal relationship to nitrogen fixation and identify efficient strains of rhizobial cultures.

Conclusions

The research program for the improvement of crops in the semi-arid tropics must be based on: 1) collection of worldwide germ plasm; 2) development of varieties or hybrids with high yield potential, disease-resistance, and high lysine content, and medium protein content with a high protein efficiency ratio; 3) improvement of drought tolerance and environmental stability characteristics of varieties; and 4) development of plant morphology to make varieties suitable for mixed cropping, companion cropping, intercropping, and relay cropping.

To achieve these objectives, ICRIASAT has started a program at Hyderabad and is collaborating with the active research programs in other countries. Financial support is being received from UNDP for sorghum and millets and the International Development Research Centre for chickpea and pigeon pea research.

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Improvement and Development of Tropical Root Crops

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Abstract An extensive review of tropical root crop improvement research is presented. The crops include sweet potato, cassava, yams, and edible aroids (taro and tannia). Emphasis is placed on important alternatives in the utilization of the crops, which must be considered when studying methods of improving yield potential. Botanical aspects and current world production are reviewed, as well as the strategies and technologies for increasing the yield potential of tropical root crops.

Résumé L'auteur procède à une vaste analyse des recherches visant à l'amélioration des plantes sarclées tropicales. Parmi elles figurent la patate douce, le manioc, l'igname et les aracées comestibles (taro et tannia). Il met en lumière les possibilités importantes d'utilisation de ces cultures, auxquelles on se doit de penser lorsque l'on étudie des méthodes permettant d'améliorer les potentiels de rendement. L'auteur passe en revue leurs aspects botaniques et en analyse la production mondiale actuelle de même que les stratégies et les techniques pouvant permettre d'améliorer les possibilités de rendement des plantes sarclées tropicales.

Introduction

Despite its origin in tropical latitudes and current efforts to reintroduce *Solanum* potato cultivation to the tropics, the present emphasis of Root Crop Improvement is confined to those root crops which originated and have been continuously cultivated in the tropical regions of the world. These crops include: sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), yams (*Dioscorea* sp.) and the edible aroids, i.e. taro (*Colocasia esculenta*) and tannia (*Xanthosoma sagittifolium*).

The improvement and development of these crops could lead to the realization of the Green Revolution, which has eluded so many of the tropical countries of the world.

In many instances, improvement of tropical root crops and development of root crop cultivation might mean the introduction of new varieties and modification of methods of cultivation which have served communities for centuries. Therefore, indigenous varieties and cultivation methods should be very carefully examined in relation to local environmental conditions, before research and development

¹Author unable to attend seminar; paper tabled at meeting.

strategies for root crop improvement are designed. It may well be that a considerable proportion of the desired improvement could be immediately achieved by modifications of cultural practices designed to exploit the yield potential of existing varieties. Performance of existing varieties will also provide clues for designing strategies for the massive increase in the yield potential of tropical root crops, to bring about a Green Revolution in these crops.

It is particularly significant to study the interaction of agriculture with food science and technology since the economic benefits to be derived from improving the yield potential of tropical root crops cannot be fully realized without parallel, local development and diversification of methods of utilization of these crops. Attention is drawn to some important alternatives in the utilization of root crops in Table 1. It is imperative that these alternatives be examined simultaneously with investigations on the improvement of the yield potential of root crops.

In the ensuing discussion of Root Crop Improvement, considerable emphasis is given to the current status of root crops since these crops are not well known and have not been extensively studied. Some botanical aspects and current world production of tropical root crops are reviewed because information available in these areas is relevant both to the limitations to crop improvement and to yield targets that may be realistically set for crop improvement programs. In the Section on Root Crop Improvement, some principles, strategies and technologies for increasing the yield potential of root crops are discussed and problems in root crop utilization outlined.

TABLE 1. Alternative approaches to the utilization of tropical root crops.

Whole plant including	
high protein foliage	vs. starchy tubers
Fresh tubers	vs. processed products
Small-scale processing	vs. large-scale processing
Industrial utilization	vs. utilization for food
Human consumption	vs. livestock feeds
Local consumption	vs. export

Status of Tropical Root Crops

Some Botanical Considerations

Recent use of *Solanum tuberosum*, subspecies *andigena* (Simmonds 1972) and other Andean species in potato breeding is a good example of how botanical information might be applied to root crop improvement. Some botanical considerations relevant to improvement of tropical root crops are discussed in the following section.

Sweet Potato

Sweet potato (*Ipomoea batatas*) does not exist today in the wild state, but its centre of origin is thought to be in tropical America. (Purseglove 1968). Early spread of the species to Southeast Asia (e.g. Polynesia and New Zealand) is, however, difficult to explain. *Ipomoea batatas* or its progenitor is thought to be a naturally occurring hexaploid ($2n = 90$) arising by amphidiploidy from a tetraploid ($2n = 60$) and a diploid ($2n = 30$) to produce a triploid ($2n = 45$), followed by doubling of the chromosomes to produce the hexaploid ($2n = 90$) (Purseglove 1968). *Ipomoea tiliacea* which occurs in the wild state in tropical America, Africa, and Asia, and bears close resemblance to *I. batatas*, has been suggested as a possible parent. Nishiyama (1961) suggested that *I. trifida* might be the progenitor of *I. batatas* based on evidence of hybridization with *I. batatas*, normal meiosis and fertile seed in resulting F_1 hybrids as well as back-crosses to either parent. The reconstruction of new sweet potato cultivars may be possible utilizing these and other *Ipomoea* species (Hozyo 1973). Interspecific hybridizations between *I. batatas*, *I. trichocarpa*, and *I. gracilis* have been achieved by Williams and Cope (1967), but only non-viable seed resulted in F_1 plants.

There is, however, considerable genetic variation in foliage and tuber characteristics among the several varieties and cultivars of sweet potato, which have been produced either by natural or controlled intraspecific hybridizations (Wilson 1967). Some characteristics which are worth closer consideration

for use in breeding programs for sweet potato improvement are:

1. Differential response to applied nitrogen by high and low leaf area sweet potato types (Tsunoda 1965).
2. Internode length, in view of its negative correlation with yield (Acland 1963).
3. Tuber shape and tuber stalk length (Lowe and Wilson 1974 *a, b*), in view of their importance for mechanical harvesting.
4. The semi-upright habit which occurs in some cultivars.

However, the sterility-incompatibility complex in the sweet potato species limits the potential genetic base available for generations of seedling populations on which selection of improved types can be done. Considerable progress has been made by hybridization within compatible groups. Understanding the mechanisms involved in the sterility-incompatibility complex is an important prerequisite for the full utilization of the genetic potential of the *Ipomoea* species. It is suggested that the use of wild types (e.g. *I. trifida*) might represent a source of genes for resistance to pests and diseases of the cultivated sweet potato.

Cassava

Cassava (*Manihot esculenta*) originated in tropical America, probably in the South Mexico-Guatemala region or northeast Brazil. The genus contains about 200 related species, many of which have been studied by Rogers (1972) with a view to classifying and defining their relationship with the cultivated cassava. The closest relative of *M. esculenta* appears to be *M. aesculifolia* but other species (e.g. *pringlei*, *rubricaulis*, *angustiloba*, and *davisii*) show greater or lesser relationships to cassava (Rogers 1972). All *M. esculenta* cultivars so far examined have a chromosome number $2n = 36$ (Magoon 1967). There is, however, considerable morphological variation within the species and Rogers (1967) has produced a computer-aided morphological classification of cultivars in species collected in the Western Hemisphere. The stage is, therefore, now well set for both intra- and

inter-specific hybridization for the improvement of cassava.

A limited number of interspecific hybridizations has already been done with some success in overcoming resistance to cassava disease. The wild species used include *glaziovii*, *catin-gea*, *saxicola*, and *melanobasis*. Thus, a considerable measure of resistance to bacterial wilt has been effected in East Africa, after several generations of back-crosses with *M. esculenta*-*M. glaziovii* interspecific hybrids (Jennings 1957, 1963). Inter- and intra-specific hybridization has also led to considerable improvement in cassava yield and resistance to disease at the Central Tuber Crops Research Station at Trivandrum in India (Magoon 1967, 1970). Magoon (1967) also suggested that production of triploid chromosomal races ($3n = 54$) of cassava might lead to the agronomic improvement of the species. It is suggested that interspecific hybridizations might be used for the introduction of the following characteristics in cultivated cassava species: 1 reduced size of the plant; 2 reduced woodiness of the stem; 3 reduced leaf abscission; 4 shorter cropping period; 5 reduced cyanogenic glucoside content of tubers; and 6 tuber shape, size, and distribution more suitable for mechanical harvesting. Although these characteristics are desirable for large-scale mechanical cultivation of cassava, attention is drawn to the suitability of some existing cultivars to cultivation by traditional methods.

Yams

Yams (*Dioscorea* sp.) differ from other cultivated tropical root crops in their apparent origin in three widely separated regions of the tropics, in south Asia, West Africa, and in northern South America (Purseglove 1968). Also, many species of *Dioscorea* have been domesticated to produce cultivated root crops, with varying degrees of agronomic potential, both in their centres of origin and elsewhere. There is apparently only one cultivated species (*D. bulbifera*) which still exists in the wild state in Asia and Africa. Some cultivated *Dioscorea* species, as well as characteristic

chromosome numbers, are listed in Table 2 (Purseglove 1968).

There is considerable variation in the chromosome numbers in *Dioscorea* species. Thus, investigations of Nakajima (1933, 1936) and Smith (1937) produced counts of $2n = 20, 40, 60, 61, 64, 80, 81, 140$ and 144 in 17 species, most of which originated in the Old World. Counts of $2n = 30, 40, 50$ and 70 chromosomes were obtained by Sharma and De (1956) for individual plants of a *D. alata* population indicating that individuals of a single species may behave as members of a polyploid series. However, since there were no marked phenotypic differences among the individuals, it was concluded that polyploidy alone was not responsible for the phenotypic changes associated with speciation in *Dioscorea*. Martin and Ortiz (1963) presented evidence to support the hypothesis that Asiatic species have chromosome numbers which are multiples of 10 and African species multiples of 9 and 10. Further evidence (Martin and Ortiz 1966) was presented to suggest that 9 is the basic chromosome number for New World species. The work of Henry (1967) with *D. trifida* supported this finding. The existence of several natural polyploids among *Dioscorea* species obviates the necessity for experimental production of ploidy as a method of increasing yield in yams.

TABLE 2. Tropical root crop species (Purseglove 1968).

East African yams	
<i>D. rotundata</i>	($2n = 36, 54, 140$)
<i>D. cayenensis</i>	($2n = 36, 54, 140$)
<i>D. dumetorum</i>	($2n = 36, 45, 54$)
<i>D. bulbifera</i>	($2n = 40, 60, 80, 100$)
South Asian Yams	
<i>D. alata</i>	($2n = 30, 40, 50, 60, 70, 80$)
<i>D. esculenta</i>	($2n = 40, 90, 100$)
<i>D. opposita</i>	($2n = 140$)
(syn. <i>batatas</i>)	
<i>D. liepida</i>	($2n = 40$)
<i>D. numularia</i>	($2n = 40$)
Tropical American yam	
<i>D. trifida</i>	($2n = 54, 72, 81$)

Genetic manipulation in *Dioscorea* species is, however, limited by restricted capacity for flowering and low viability of seed in the most agronomically developed species (e.g. *alata* and *rotundata*). Seed viability in the American species *D. trifida* is notably better than in other species and together with high quality of its tubers (albeit with low yields) this species perhaps represents the most promising starting point for genetic manipulation. The existence of the bisexual flowering habit in many *Dioscorea* species might be an advantage in the technological achievement of hybridization.

The statement by Purseglove (1968) that the early members of the Dioscoraceae were "lowly herbs which evolved annual twining stems as a means of attaining light without abandoning positions affording shelter for their rootstocks, when weather turned against them" suggests that a non-twining herbaceous habit might be recapitulated by genetic manipulation. If such manipulation can be achieved, while still maintaining superior tuberization characteristics and development of the capacity for rapid growth, an ideal yam cultivar might be obtained. Undesirable characteristics which might be modified in existing yam species include: 1 slow early growth; 2 delayed onset of tuber bulking and, hence, extended cropping periods; and 3 superabundance of foliage on long twining stems. A major obstacle to modifying these characteristics by genetic manipulation is the failure to produce viable seed in many yam species. Studies aimed at correcting this deficiency in *Dioscorea* species are therefore a prerequisite for yam improvement. However, controlled intraspecific hybridization in *D. trifida* has been achieved by Henry (1967) and recently cultivars of *D. rotundata* produced a viable seed in abundance in Nigeria (S. Sadik 1973 private communication).

Edible Aroids

The edible aroids (*Colocasia esculenta* and *Xanthosoma sagittifolium*) are perhaps the root crops which show least capacity for flowering and setting fertile seed. Many *Colo-*

casia cultivars, variously named taro, dasheen, cocoyam, or eddoe do not normally flower and seeds have been reported on only three occasions (Purseglove 1972). In *Xanthosoma* (tannia, yautia, cocoyam), most cultivars seldom flower and seeds are very rarely produced. As in *Dioscorea* species, study of methods of flower and viable seed induction in the edible aroids is a prerequisite for crop improvement.

Colocasia esculenta occurs wild in Southeast Asia and is widely cultivated in this region. The species reached the eastern Mediterranean in classical times (A.D. 23–79) and is now distributed worldwide. Many cultivars are recognized and there is a taro collection in Hawaii. Barrau (1957) reported work in which Melanesian, Micronesian, and Polynesian clones showed a diploid chromosome number of $2n = 28$, while in New Zealand and New Caledonian clones, chromosome numbers of $2n = 42$ were observed.

There are two major types of *Colocasia*: those in which there is one main central corm (taro or dasheen) and others in which there is a smaller central corm and numerous laterally produced cormels (eddoe). These differences together with differences in the length of the sterile appendage of the spadix prompted Purseglove (1972) to distinguish between *C. esculenta* var. *esculenta* (taro) and *C. esculenta* var. *antiquorum* (eddoe). I am not aware of any collection of *antiquorum* cultivars.

The long cropping period of 8–10 months, as well as the use of flooded conditions for cultivation, are areas where agronomic improvements might be made. However, adaptability to wet conditions in many tropical areas is a valuable asset of this crop.

Xanthosoma sagittifolium (tannia) can be easily distinguished from *Colocasia* by their sagittate or hastate leaves, compared with the oblongovate leaves of *Colocasia*. *Xanthosoma* was domesticated in the New World and has only recently been distributed throughout the tropics. The chromosome number ($2n = 26$) suggests that *X. sagittifolium* is a diploid since in the genus *Xanthosoma* chromosome numbers of $2n = 12, 13$ are found.

Gooding and Campbell (1961) recognized at least 15 cultivars in the Eastern Caribbean in which colour of tuber flesh ranged from white through yellow to pink.

The pattern of tuberization in tannia is similar to eddoe in that ten or more lateral cormels are produced on a central corm. Spence (1970) referred to the high turnover of leaves during the 10–12-month growth period of the crop and suggested that crop efficiency and yield might be improved by selection for lower leaf turnover. As in most other tropical root crops excepting sweet potato, reduction of the 10–12-month crop period in tannia would also lead to increased crop efficiency.

Cultivation, Production, and Productivity

Cultivation

In many tropical countries, root crops are produced by subsistence farmers on small, scattered plots, as part of an intricate intercropping system, under shifting cultivation (Coursey and Haynes 1970). The importance of such root crop production is very often underestimated because it represents the food supply of remote, local communities rather than being an item of international trade.

Cassava is particularly suited to subsistence cultivation because of its tolerance of a wide range of ecological conditions, producing satisfactory yields on relatively poor soils unsuitable to most other crops. Cassava also yields more calories per unit of labour effort and is relatively more resistant to pests and diseases than most tropical crops, particularly under conditions of shifting, intercropped subsistence systems of cultivation. In addition, cassava tubers can remain in the ground for considerable periods without serious loss of dry matter and for this reason is often cultivated as a “famine crop” (Coursey and Haynes 1970).

The relative ease of cultivation of cassava could, however, be a serious impediment to the improvement of the crop, both in the thinking of research and development planners as well as in the attitude of farmers to improved cultivation techniques.

Subsistence methods of cultivation in cassava contrasts sharply with the status of sweet

potato cultivation in Japan, Taiwan, and the southern U.S., where modern agricultural methods have been applied to sweet potato with considerable increases in yield. Although sweet potato is a more labour-intensive crop than cassava, it has the important advantage of perhaps the shortest cropping season of all tropical root crops. Realization of the possibility of cultivating up to three sweet potato crops per year in the tropics will result in a tremendous production of raw material both for food as well as for industrial use.

As grown by subsistence-level farmers, yams in West Africa and taro in Oceania are both more labour-intensive than cassava and have longer cropping seasons (8–12 months) than sweet potato. These crops are, however, highly valued and have social and traditional significance in the tropics (Coursey 1967, 1973). With progressive urbanization of developing countries, yams and edible aroids perhaps face the greatest danger of being replaced either by more efficient root crops or by cereals as energy foods, unless methods for improving their production efficiency are implemented in the near future.

Production and Productivity

Estimates of annual tropical root crop production in different regions of the world, collected from the FAO Production Year Book (1971) are compared with *Solanum* potato production in Table 3. It is significant that the production of tropical root crops (ca. 150 million metric tons) is only 60% that of potato production at 250 million metric tons. Cassava production (90 million metric tons) represents some 60% of tropical root crops production, with Latin America 35 million metric tons and Africa 37 million metric tons accounting for 60% of tropical root crop production. Sweet potato and yam production together account for approximately 50% of world production of cassava. Production figures for yams and sweet potato are not distinguished in the FAO Production Year Book, but Coursey (1967) estimated that 41% of the total represents yam production and 59% sweet potato production. On this basis, sweet potato production amounts to 26.3 million tons and yam production 18.2 million tons. Production figures for the edible aroids are omitted from the FAO Production Year Book,

TABLE 3. Comparative estimates of tropical root crop production, 1970
(million metric tons)

Region	Crop			Total
	Cassava	Yam & sweet potato ^a	Potato	
Latin America	34.82	4.12	8.51 (S.A.) ^b	47.45
Near East	0.14	.09	—	.23
Far East	20.12	15.99	13.63 (A) ^b	49.74
Africa	37.02	23.41	2.74	63.17
Oceania	0.12	0.18	1.01	1.31
Europe	—	.08	134.70	134.78
			92.30 (USSR)	92.30
North America	—	0.63	2.34 (N&CA) ^b	2.97
Total	92.22	44.50	255.23	391.95
Total root crop production: 401.95 million tons.				

^aYam and sweet potatoes are not distinguished in the FAO production Year Book (1971). Coursey (1967) estimated yam production at 41% and sweet potato 52% of the FAO totals. Coursey and Haynes (1970) estimated edible aroid production at 10 M. tons.

^bA, Asia; S, South; N&CA, North & Central America.

although these root crops are important sources of food, especially in Oceania. Coursey and Haynes (1970) estimated an annual production for aroid crops of 10 million tons.

Comparatively low levels of tropical root crop production are due mainly to low productivity (Table 4). Thus, approximately equal acreages of land are under potato (22.46 million ha) and tropical root crop (24.87 million ha), and hence productivity of the latter crops (90×10^2 kg/ha) is only 66% that in potato (136×10^2 kg/ha). Use of superior varieties is an important factor in increasing productivity.

Cassava productivity in Latin America (136×10^2 kg/ha) is only 71% of potato productivity in Europe at 190×10^2 kg/ha, which is 30% higher than the world average (136×10^2 kg/ha). Latin American cassava productivity is, however, some 45% higher than the average global cassava productivity. Also, cassava production in Africa (37 million tons), which accounts for some 40% of world production, is achieved at the low productivity of 75×10^2 kg/ha or 55% of Latin American cassava productivity. Data in Table 5 show the comparative root crop productivity in

some countries with relatively high root crop production. Increase in the productivity of cassava in the seven cassava-producing countries shown, to the level achieved in India (152×10^2 kg/ha) in 1970, would result in an immediate 40% increase in the total cassava production (91 million tons) of the countries compared. Such increased productivity is particularly important in Nigeria and Indonesia, where cassava production could be increased by 44 and 55% respectively, by increasing productivity to the Indian level (152×10^2 kg/ha). Similar increased production could be achieved by increasing the low yam productivity in Zaïre, Nigeria, and India, through improvement in current cultural practices.

One of the factors responsible for low productivity in tropical root crops is the existing uncontrolled depredations of pests and diseases. Although the effects of many of these pests and diseases can be restricted by chemical control methods, high cost of control often militates against widespread use of these methods. Control of weeds also suffers from the same disadvantage. The achievement of increased productivity in tropical root crops de-

TABLE 4. Comparative estimates of tropical root crop productivity, 1970
(100 kg/ha).

Region	Crop			Average
	Cassava	Yam and sweet potato ^a	Potato ^b	
Latin America	136	91	80 (S.A.)	102
Near East	78	85	—	82
Far East	90	101	105 (A)	99
Africa	75	72	82	76
Oceania	112	102	191	135
Europe	—	162	190	176
			116 (USSR)	116
North America	—	114	123 (N&CA)	119
Average	98	104	127	110
Avg productivity = 88×10^2 kg/ha				

^aYam and sweet potatoes are not distinguished in the FAO Production Year Book (1971). Coursey (1967) estimated yam production at 41% and sweet potato 59% of the FAO totals.

^bA = Asia; S = South; N&CA = North & Central America.

TABLE 5. Comparative productivity of countries with relatively high root crop production. Production, million metric tons; productivity, 100 kg/ha. Extracted from FAO Production Year Book 1971.

Region/Country	Cassava		Region/Country	Sweet potatoes and yams	
	Production	Productivity		Production	Productivity
Africa			Africa		
Zaire	10.00	125	Nigeria ^b	13.50	75
Nigeria	7.30	66	Ghana ^b	1.62	94
Americans			Americans		
Brazil	29.46	146	Brazil ^{a,b}	2.13	118
Colombia	1.20	80	USA	0.63 ^a	115
Asia			Asia		
Indonesia	10.45	73	Taiwan ^a	3.44	151
India	5.22	148	Indonesia ^{a,b}	3.03	85
Thailand	1.97	152	Japan ^b	2.56	199
			Korea (Rep) ^b	2.14	168
Total avg	65.60	113	Total avg	29.05	106
World total avg	92.22	98	World total avg	44.50	102

^aSweet potato production.

^bYam production.

pendes therefore on the development of relatively cheap methods of control of pests, diseases, and weeds.

Crop Efficiency

A significant feature of the status of root crops in the tropics is the multiplicity of crop species cultivated, compared with the almost exclusive cultivation of *Solanum tuberosum* in temperate climates. One important consideration in improving root crop production is a comparison of the relative crop efficiencies of these root crops and their evaluation against efficiencies in grain crops grown in the tropics. Such consideration might lead to emphasis in the single tropical root crop species. Alternately, consideration of crop efficiencies in relation to suitability of species to different riches in the tropical environment, consumer preference, and availability of technology for utilization might result in diversification of effort for root crop improvement to several of the existing root crop species.

De Vries et al. (1967) reported an analysis of average world production data for a num-

ber of tropical food crops (Table 6) which emphasized the following points: 1 Although root crops produced more bulk than grain crops, because of their higher water content, the average energetic food value of root crops (121 cal/100 g) amounted to only 34% of that of grain crops (354 cal/100 g); and 2 However, when differences in the percentage edible yield as well as the relative periods of vegetation of the crops are taken into consideration, then the average crop efficiency of root crops (38.5×10^3 cal/ha/day) was slightly higher than that for grain crops (36.9×10^3 cal/ha/day). Data in Table 6 also indicated that cassava had the highest energetic productivity of 11.6×10^6 cal/ha. However, the shorter period of vegetation of sweet potato resulted in its higher crop efficiency at 48×10^3 cal/ha/day compared with cassava (35×10^3 cal/ha/day).

Further comparisons of maximum crop efficiencies calculated from highest experimental yields (Table 7) showed that the average crop efficiency of cassava and sweet potato (215×10^3 cal/ha/day) was some 43% higher than that for grain crops in the tropics

TABLE 6. Average world production of a number of tropical root crops.^a

Crop	Tons/ha (1)	Cal/100 g (2)	Edible portion (3)	Cal/ha 10 ⁶ (4)	Period of vegetation (5)	Cal/(ha·day) 10 ³ (6)
Rice	2.0	352	70	5.0	150	33
Wheat	1.2	344	100	4.1	120	34
Maize	2.1	363	100	7.6	135	56
Cassava	9.1	153	83	11.6	330	35
Sweet potato	6.5	114	88	6.5	135	48
Yam	8.0	104	85	7.1	280	25
Colocasia	5.8	113	85	5.5	120	46

^aFrom De Vries et al. 1967.TABLE 7. Maximum yields in selected experiment stations in the tropics.^a

Crop	<i>tons/ha per harvest</i>		<i>tons/ha per yr</i>		Cal/ha · day) 10 ³ (3)	Rate of breeding (4)
	source		source			
	tons	(1)	tons	(2)		
Rice	16.4	IRRI (1965)	26.0	Datta et al. (1966)	176	***
Wheat	3.9	INEAC (1963)	11.7	INEAC (1963)	110	*
Maize	5.5	INEAC (1959)	20.0	APL (1937)	200	**
Cassava	77.0	van der Zijl (1930)	71.1	APL (1937)	250	**
Sweet potato	41.0	INEAC (1963)	65.2	APL (1937)	180	*
Banana	39.0	INEAC (1963)	39.0	INEAC (1963)	80	—

^aFrom De Vries et al. 1967.

at 150×10^3 cal/ha/day. Also, cassava efficiency (250×10^3 cal/ha/day) was 25% higher than that for maize (200×10^3 cal/ha/day) and 44% higher than rice at 176×10^3 cal/ha/day. Calculations for *Colocasia*, *Xanthosoma*, and yams (*D. alata* and *D. rotundata*) gave maximum efficiencies in the region of 100×10^3 cal/ha/day.

Root crops are therefore comparable to grains as sources of the world supply of energy foods and have contributed to world food production for long periods in history. Root crops can also compete favourably with grain crops in the efficiency of such production. Further, the existence of a variety of root crop species allows for the selection and improvement of individual crops to meet specific niches in the tropical environment. The potential for such root crop improvement would

seem to be tremendous, since most of these crops have not been subjected to the intensive breeding already accomplished in both their temperate counterpart, *Solanum* potato, as well as in their grain competitors in the tropics, rice and maize. The achievement of this potential will result in an equally urgent demand for specialists in food science to improve existing, local methods of utilization of root crops to levels compatible with modern processing technology.

Research Institutions

Root crop research has been neglected for a long time, partly because tropical root crops suffered from the stigma of subsistence level crops for remote populations and also because these crops have not contributed greatly to

TABLE 8. Percentage contribution of root crops to diets in different regions of the world.^a

Region	% contribution of root crops to diets
Near East	6.4%
Far East	10.7%
Latin America	14.5%
Africa	29.2%

^aFrom Lucas 1968.

international trade. Nevertheless, these crops provide a considerable proportion of the diets of tropical peoples. Lucas (1968) reported the contributions of root crops to regional diets on the basis of FAO figures (Table 8). For this reason alone, root crops warrant considerable research attention.

The status of root crop research has, however, improved considerably since the realization of the First International Symposium on Tropical Root Crops held at the University of the West Indies, St. Augustine, Trinidad, West Indies (2-9 April 1967). The symposium moved to the University of Hawaii on 23-30 August 1970 where plans for launching an International Society for Tropical Root Crops on 1 January 1971 were made. The Society mounted the Third International Symposium on Tropical Root Crops at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, 2-9 December 1973, and the fourth Symposium will be held at Centro Internacional de Agricultura Tropical (CIAT) in 1976.

Since the organization of the first Symposium in 1967, two international institutes, IITA and CIAT, with major programs in tropi-

cal root crop research, have been inaugurated and there were significant contributions at the Ibadan symposium from these Institutes on many aspects of root crop research. It is expected that these contributions will be increased in the future and that the institutes together with the society will serve as a stimulus for improvement of the global research effort in tropical root crops.

Table 9 indicates some of the research manpower that exists for solution of problems in root crop improvement. However, only a small proportion of the work reported in the three symposia was on root crop utilization. Research has been confined mostly to agronomic aspects of root crop production. Although the development of processing depends on the adequate production of raw material, it is felt that utilization studies should parallel production studies in tropical countries, so as to encourage the efficient utilization of a high percentage of tropical root crops in regions where they are produced.

Proceedings of the 1st and 2nd International Symposia on Tropical Root Crops provide the most complete accounts of research activities on root crops up to 1970. The proceedings of the Ibadan symposium which will be published in 1974 will report a considerable proportion of the research effort in root crops since that time.

Root Crop Improvement

Three aspects of tropical root crop improvement may be considered: 1 current production; 2 yield potential; and 3 utilization. In the discussion, improvement of current production using the best available varieties and cultural practices is omitted since this

TABLE 9. Approximate attendance of scientists at international Symposia on Tropical Root Crops.

	Africa	Asia	Latin America	North America	Europe	Totals
1st Symposium (1967)	3	2	94	15	6	120
2nd Symposium (1970)	3	20	20	40	4	87
3rd Symposium (1973)	87	9	14	7	18	135
Totals	93	31	128	62	28	342

is within the reach of national and international institutions currently working in this area. Emphasis is given to improvement in the yield potential of tropical root crops, since it is felt that the long-term survival of these crops as important sources of carbohydrate foods may be threatened by rapid, current progress and projected targets in the development of tropical and subtropical cereals (e.g. rice and maize). It is also urgent that the technology for the efficient utilization of root crops should be available to coincide with the massive increase in root crop production that could accrue from a fundamental improvement in the yield potential of root crops.

Improvement of Yield Potential

Improvement of the yield potential of tropical root crops depends on precise definition of the targets for the improvement of root crop production and productivity,the principles that might be used in achieving these targets, and strategy for root crop improvement.

Targets for Improvement

Many researchers concerned with fundamental aspects of the improvement of crop yields have emphasized the poor utilization of solar radiation by crops for the production both of total dry matter and of crop yield (San Pietro et al. 1967). Loomis and Williams (1963) and Lemon (1966) estimated that only approximately 7% of the visible radiation available for photosynthesis was realized in dry matter production. Loomis and Williams (1963) calculated the net production of carbohydrate by a crop surface receiving 500 cal/cm²/day at 71 g/m² (Table 10).

The gross potential dry matter production under an average half-clouded sky was estimated by De Witt (1965) at approximately 275 carbohydrate equivalents per hectare per day (i.e. 1100 × 10³ cal/ha/day). Data in Table 7 indicate that at maximum current cassava productivity only 23% of this available energy or 250 cal/ha/day is realized in tuber yield. Thus, of the 7% utilization of visible radiation available for total carbohydrate production, only 23% is accounted for in cassava

TABLE 10. Estimation of potential daily production by a crop surface receiving 500 cal/cm². day.^a

Potential Production	
1. Total radiation/day	500 cal/cm ²
2. Visible radiation, 400/700 mμ	222 cal/cm ²
3. Total quanta, 400–700 mμ	4320 μEinsteins/cm ²
Albedo loss	–360 μEinsteins/cm ²
Inactive absorption	–432 μEinsteins/cm ²
4. Total available for photosynthesis	3528 μEinsteins/cm ²
5. [CH ₂ O] produced	353 μmole/cm ²
6. Respiration loss	–116 μmole/cm ²
7. Net production of [CH ₂ O]	237 μmole/cm ²
Net production in grams 71 g/m ²	
% total visible radiation 6.7	

^aAdapted from “Maximum crop productivity: an estimate,” R. S. Loomis and W. A. Williams, *Crop Science* 3: 67–72 (1963) by J. T. Army and F. A. Greer in *Harvesting the Sun*.

tuber yield. Accordingly, yield in cassava represents only approximately 1.6% of the radiation available for photosynthesis.

Based on calculations of the performance of ideal root crops with respect to early ground cover by the crop canopy and improved distribution of dry matter to yield organs, de Vries et al. (1967) estimated a possible net potential production of dry matter of 550 × 10³ cal/ha/day or one-half of the gross potential production. Such production by superior varieties grown under conditions of improved cultural practice would result in the following productivity:

Cassava	140 tons/ha/year
Sweet potato	200 tons/ha/year
Rice	80 tons/ha/year
Maize	50 tons/ha/year

Calculations based on more efficient utilization of available radiation would result in yield targets for yams and edible aroids of the same order as those for cassava and sweet potato. Data in Table 7 show that realization of the suggested yield targets involves two- to three-fold increases in the highest current experimental productivity both in tropical roots

and grains. However, it is felt that such yield targets for root crops are within the reach of modern research techniques, especially as the habit of these crops has not as yet been altered significantly from that of existing wild species for increased light utilization, as has been achieved in rice and maize.

Principles for Improvement

Undoubtedly, the clarification of principles for long-term root crop improvement must be centred around the more efficient utilization of radiant energy for tuber yield productivity. Three fundamental physiological limitations are involved in the low (1.6%) utilization of visible radiation by root crops for yield production (Table 11). Obviously, these limitations are by no means restricted to those of the process of photosynthesis as shown in limitation 3 (Table 11). Indeed, it is doubtful

whether the process of photosynthesis per se is the most immediate factor limiting yield in many root crop species. Rather, low light utilization association with characteristics of root crop development and morphogenesis, as well as the distribution and utilization of assimilate for growth of the individual plant and the crop community, implied in limitations 1 and 2 (Table 11) may provide more immediate solutions to improvement.

Questions relevant to improvement in the utilization of radiant energy for increased tuber yield therefore include:

a. *Shoot growth and crop growth patterns*

1 Is early growth of root crop species to be increased by increasing the rate of carbon dioxide reduction in photosynthesis or by nitrate reduction in nitrogen metabolism, shown to be the limiting step in protein synthesis? 2 Should an upright habit be sought as an immediate objective in breeding programs for tropical root crops (sweet potato, yams), or do the advantages of earlier closed canopy afforded by the trailing habit of sweet potato, outweigh the increased light interception in an upright plant? 3 Can yams be converted to trailing plants like sweet potato and would such a conversion increase light utilization compared with staked yam crops? 4 Does the production of a superabundance of lignified stem tissue in cassava represent inefficient utilization of assimilate, and the rapid turnover of leaves in edible aroids (Spence 1970) a similar loss of assimilate in terms of tuber yields? 5 What is the percentage reduction in light utilization due to high leaf area indices (e.g. in yams)? 6 How important is selection for leaf orientation and/or leaf shape and capacity for tropistic leaf movement (e.g. in sweet potato and cassava) for increasing light interception in root crop canopies?

b. *Tuber initiation and tuber bulking*

7 Can the growth period available for tuber bulking be increased by earlier tuber initiation or is the advent of tuber bulking itself subject to a specific stimulatory influence? 8 To what extent is the rate of

TABLE 11. Physiological limitations to radiant energy utilization by root crops.

1. *Inefficient light interception by the crop canopy*
 - (a) Low percentage light interception in the intervals between
 - (i) planting and achievement of closed canopy
 - (ii) onset of leaf senescence and harvest of tubers
 - (b) Inefficient utilization of light energy due to mutual shading of leaves at maximal L.A.I.^a
2. *Relative distribution of assimilate to foliage and tubers*
 - (a) Superabundance of leaf production at mid-crop
 - (b) Delayed initiation and bulking of tubers
 - (c) Rate of translocation of assimilate to tubers
 - (d) Rate of accumulation of assimilate in tuber storage cells
3. *Inefficient net conversion of light energy to carbohydrate*
 - (a) Low efficiency of photosynthetic conversion of light energy to carbohydrate
 - (b) Respiratory losses of fixed carbon in carbohydrate and glycolate.

^aL.A.I., leaf area index.

photosynthesis increased by the “sink” effect of tuber bulking?

c. *Translocation and storage of assimilate in tubers* 9 Can the rate of translocation of assimilate to tubers be increased in root crops to increase tuber yield? 10 Conversely, can the rate of accumulation and storage of such assimilate be improved by increasing the cellular growth of tubers (Wilson and Lowe 1973)?

These morphogenetic and developmental factors are perhaps more important than the process of photosynthesis in the development of a strategy and technologies for implementing the basic principle for crop improvement: the increased utilization of radiant energy for yield productivity.

Strategy for Improvement

Four stages are recognized in the strategy for yield improvement in tropical root crops: 1 Collection of varieties of cultivated and related species; 2 Preliminary screening using slection based on morphological, morphogenetic, and agronomic characteristics; 3 Development of technologies for investigating the physiological limitations to yield potential improvement in cultivars; and 4 Controlled hybridizations for development of superior cultivars.

Collection of Varieties

Although there are many difficulties, including problems of plant quarantine, in the

establishment of collections, it is of utmost importance that complete collections of all cultivated root crop species be established. It is only in this way that misunderstandings in the nomenclature, classification, and recognition of cultivars could be cleared up. Growth of cultivar collections under similar environmental conditions is also necessary for subsequent evaluation of morphological and agronomic characteristics.

There are at least four collections of individual root crop species known to me (Table 12). Although these collections include root crops of major importance, they are by no means complete and significant collections of *Xanthosoma sagittifolium* (tannia) and *Dioscorea trifida* apparently do not exist. However, in addition to the major collections listed in Table 12, there are smaller national and institutional collections in different regions of the world (e.g. there are small collections of *Xanthosoma* and *D. trifida* at U.W.I., St. Augustine, Trinidad).

An important recommendation for the improvement of root crops must be the establishment of complete collections so that the full range of genetic variability in the species could be made available to scientists in the field of root crop improvement.

Preliminary Screening of Cultivars

The objectives of the preliminary screening process are first to classify root crop varieties on the basis of morphological characters and second to evaluate the varieties on the basis of

TABLE 12. Some important root crop collections.

Root crop	Location	No. of varieties (approx.)
<i>Manihot esculenta</i>	CIAT, Cali, Colombia	2000
	Central Tuber Research, Kerala, India	
<i>Ipomoea batatas</i>	Yen Pacific Collection, National	600
	Institute of Agricultural Science, Japan	
<i>Colocasia esculenta</i>	University of Hawaii, Hawaii, USA	154
Africa yams <i>D. rotundata</i> / <i>cayenensis</i> / <i>bulbifera</i>	Martin Collection, Federal Experiment Station,	100
	Mayaguez, Puerto Rico, USA	

morphogenetic and agronomic characteristics relevant to improvement of the yield potential of the species. Here, attention is drawn to the work of Rogers (1967) and Flemming and Rogers (1970) on the computer-aided classification of *M. esculenta* (cassava) varieties. Such taxonomic studies should be completed for cassava and other cultivated root crop species. Rogers has also completed a descriptive classification of *Manihot* species related to *M. esculenta* and in view of the possible significance of these species for interspecific hybridizations for cassava improvement, it is extremely important that a collection of these *Manihot* species be established.

The objective of preliminary screening for morphogenetic and agronomic characteristics is to quickly reduce the large number of varieties and cultivars in most root crop species to a smaller number of types containing the germ plasm for improved yield potential. It is necessary to effect this reduction in order to conduct precise physiological experiments on the relative contribution of each of the limitations to yield (Table 11), toward the overall restriction of the yield potential of existing cultivars. It is accepted that this preliminary screening process will be of necessity imprecise and hence complete collections must be available to agronomists, physiologists and breeders for repeated reevaluations. Such

screening could, however, be very useful in defining priorities for research on the principle that the limitation with the highest percentage contribution to yield restriction should be first eliminated.

It is suggested that the preliminary screening process might be conducted on the basis of contrasting characteristics so as both to facilitate precise recognition of individual limiting factors and more important to allow for experimental controls in physiological evaluations. The following characteristics (Table 13) might form the basis for preliminary screening of cultivars for morphogenetic and agronomic characteristics. These characteristics emerge from considerations of the limitations to yield mentioned in Table 11. Pest and disease resistance is included in this preliminary screening since there is evidence for the occurrence of considerable resistance in unimproved cultivars. Also, the realization of full yield potential is considerably frustrated in improved cultivars by susceptibility to insect and nematode pests as well as fungal, bacterial and virus diseases.

Technologies for Investigating Physiological Limitations to Yield Potential Improvement

Investigations on the physiological limitations to yield potential improvement are en-

TABLE 13. Suggested characteristics for preliminary screening of root crop collections.

Principle	Contracting characteristics
Light interception	Rapid vs. slow early growth
	Early vs. late senescence of foliage
	High and low leaf area indices at mid-crop
	Elongated vs. shortened stems
	Entire vs. divided leaf shape
	Horizontal vs. vertical leaf orientation
Distribution of assimilate	High vs. low total dry matter production
	Early vs. late tuberization
	High vs. low total dry matter yield
	High tuber number vs. low tuber number
	High vs. low mean tuber weight
Pest and disease resistance	Globular vs. elongated tuber shape
	Screening for resistance to insect nematode pests and fungal, bacterial, and virus diseases

visaged as the most important stage in the strategy for improvement of root crops. Evidence for the validity of this physiological approach to yield improvement is derived from examination of the results of breeding programs based on phenotypic selection of individual plants. Thus, van Dobben (1962) drew reference to the unwitting selection for improved dry matter distribution by Dutch plant breeders in the development of winter wheat varieties over a 25-year period. (Table 14). There are many other instances in which physiologists belatedly discuss and explain the mechanism of increased yield in superior cultivars, after they have been produced by breeders. On the other hand, it is quite possible that breeders may miss ideal opportunities for full realization of the potential of the species in the absence of a physiological input to breeding programs, by discarding low-yielding types with otherwise superior crop performance characteristics (e.g. light interception.) The physiological approach to yield improvement in root crops is further justified because in many instances conventional breeding and selection have apparently led to ceiling yields (e.g. sweet potato). Also, the poor flowering in many species is a serious handicap to hybridization.

There are two possible technologies that are available for examining the physiological limitations to improved yield potential: (1) design of an ideal crop ideotype based on physiological considerations (Donald 1968), and (2) formulation of ideal plant types for different environmental conditions through comparative analysis of existing cultivars, with

TABLE 14. Total yield and grain/straw ratio of leading winter wheat varieties in The Netherlands.

Variety	Period	Wt of straw and grain (kg/ha)	Grain/straw
Wilhelmina	1902-32	12,600	0.51
Juliana	1934-47	12,430	0.55
Staring	1948-61	13,900	0.59
Felix	1958-61	12,830	0.60
Heines VII	1953-55	11,860	0.66

contrasting characteristics. Arguments for and against these technologies will not be discussed here since it is felt that the analytical criteria which must be used in the preliminary screening process to some extent presuppose the characteristics of ideal cultivars. However, the main objective of physiologists involved in root crop improvement should be the development of a common technology so as to avoid undue repetition of similar experiments, especially on the same root crop species.

Growth Analysis

Perhaps the most valuable tool in the evaluation of the limitations to yield potential improvement in root crops is the growth analysis technique. The preceding diagrams and tables illustrate the use of this technique in the evaluation of light interception and assimilate distribution as factors affecting the yield potential in root crop species and in individual cultivars within a single species.

In Tables 15 and 16, a comparative analysis

TABLE 15. Time scale for leaf area index (LAI) development in some root crops (weeks).^a

Crop	Time scale, LAI development (weeks)						Total time (weeks)
	LAI<1	LAI>1<3	LAI>3	(LAI max)	LAI<3>1	LAI<1	
<i>Solanum</i> ¹ (tropical)	4.0	1.6	4.0	(5.3)	4.4	—	14.0
<i>Solanum</i> ² (temperate)	6.5	3.5	9.0	(4.0)	1.5	1.5	22.0
<i>Ipomoea</i> ³	4.5	3.5	5.5	(4.0)	12.5	—	26.0
<i>Xanthosoma</i> ⁴	6.0	8.0	12.0	(4.0)	10.0	10.0	36.0
<i>D. alata</i> ⁵	9.0	8.0	8.0	(4.0)	6.5	2.5	34.0
<i>D. esculenta</i> ⁶	14.0	4.0	21.5	(10.0)	1.0	—	40.5
<i>D. trifida</i> ⁷	17.0	10.0	6.5	(3.5)	4.5	2.5	40.5

TABLE 16. Time scale for leaf area index (LAI) development in some root crops (% total crop time).

Crop	Time scale, LAI development (% total crop time)					
	LAI<1	LAI>1<3	LAI<3	LAI>3	LAI<3>1	LAI<1
<i>Solanum</i> ¹ (tropical)	28.6	11.4	40.0	28.6	31.4	—
<i>Solanum</i> ² (temperate)	29.5	16.0	45.5	40.9	6.8	6.8
<i>Ipomoea</i> ³	17.4	13.4	30.8	21.1	48.1	—
<i>Xanthosoma</i> ⁴	20.0	6.7	26.7	40.0	13.3	20.0
<i>D. alata</i> ⁵	26.5	23.5	50.0	23.5	19.1	7.4
<i>D. esculenta</i> ⁶	34.5	9.9	44.4	53.1	2.5	—
<i>D. trifida</i> ⁷	41.6	24.7	66.3	16.0	11.1	6.6

^aCalculated from the following authors: ¹Chapman (1967); ²Radley (1963); ³Walter (1966); ⁴Enyi (1973); ⁵Chapman (1965*b*); ^{6,7}Ferguson and Haynes (1969).

of the capacity for light interception in different root crop species is made with reference to LAI = 1 (complete ground cover) and LAI = 3 (optimal light interception for assimilate production). The data indicate that some 50–60% of the total crop growth cycle is utilized in achieving optimal LAI at 3 in yams compared with 27–31% in *Xanthosoma* and *Ipomoea* species. Although differences of a smaller order are expected between cultivars of the same species, there is undoubtedly sufficient evidence for selection for rapid early establishment of optimal LAI (e.g. in sweet potato; Haynes et al. 1967; Tsunoda 1965; Austin and Aung 1973). Williams and Ghazali (1969) drew reference to the importance of light interception as determined by leaf shape as a factor affecting yield in three cassava cultivars of contrasting leaf shapes. (Fig. 1 and 2).

In Fig. 3 and 4 a comparative assessment of LAI development and tuber bulking in different crop species is presented. The data show that there are two growth patterns involved in tuber bulking, i.e. initiation of tuber bulking simultaneously with leaf area development (Fig. 4) and initiation of tuber bulking after the attainment of maximal LAI (Fig. 3). It is also evident that high tuber yields could be achieved by either a slow rate of tuber bulking over an extended crop growth cycle (e.g. yams) or rapid rate of tuber bulking over a short crop growth cycle (e.g. sweet potato).

In view of the reduced light interception early in crop growth, the decision to reduce the duration of crop growth cycles for increased crop efficiency will not be justified, unless such reduction in crop growth cycles also results

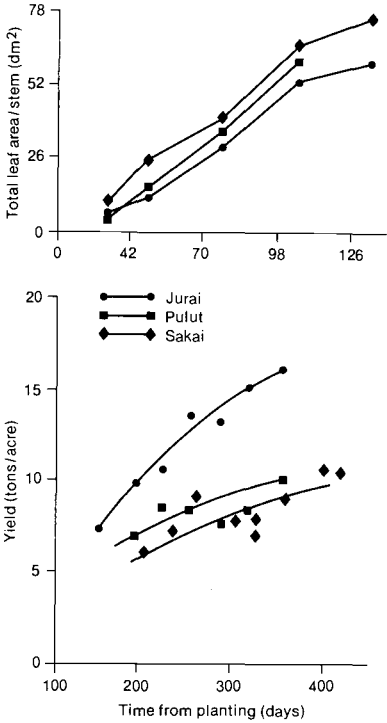


FIG. 1. (top) Leaf area trends in shoots of three tapioca varieties.

FIG. 2. (bottom) Yields of three varieties of tapioca (Chan 1967).

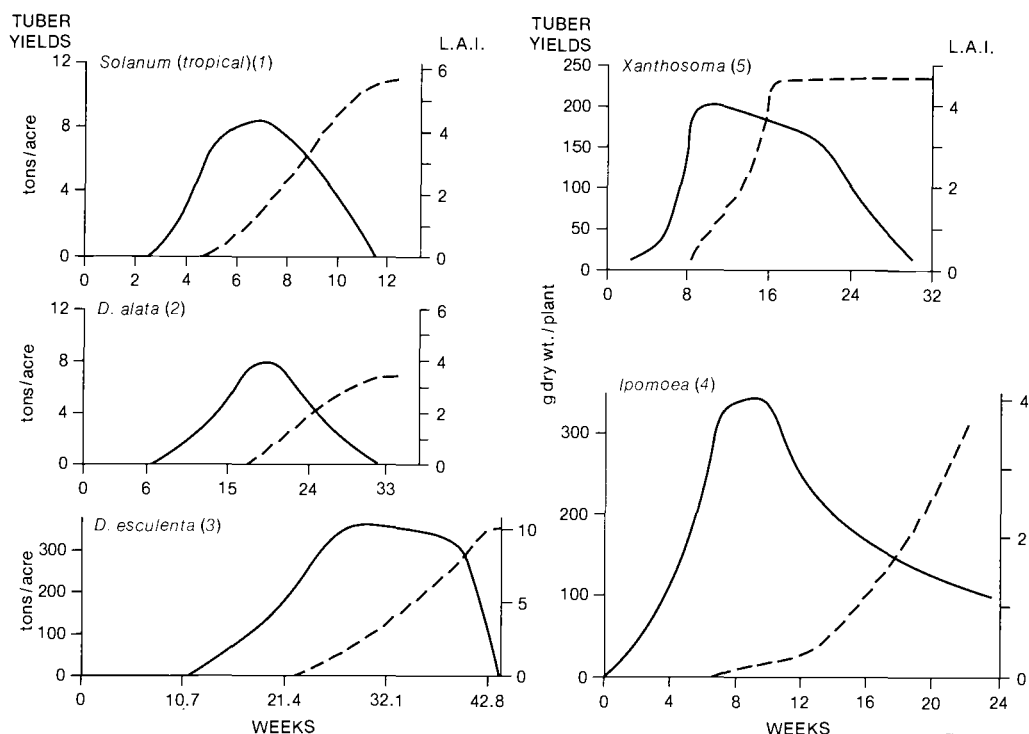


FIG. 3. Growth pattern of root crops, adapted as follows: (1) Chapman 1965a, (2) Chapman 1965b, (3) Ferguson and Haynes 1969, (4) Walter 1966, and (5) Enyi 1973.

in substantial increases in total light interception, as well as earlier tuber bulking. High experimental crop efficiencies in cassava (Table 7) argues in favour of longer crop growth cycles. However, the equally high efficiency in sweet potato is an important attribute of this crop, especially as year-round cultivation is possible under tropical conditions.

The importance of leaf area indices as determinants of crop growth rate, and rate of tuber bulking in sweet potato and cassava respectively, is illustrated in Fig. 5, where the negative effects of high LAI on these parameters are shown.

In Fig. 6, the difficulties involved in selection of the ideal cultivar based solely on results of growth analysis are demonstrated (Lowe and Wilson 1974). Thus, high-yielding sweet potato cultivars exist in which tuber bulking occurs both simultaneously with leaf development (e.g. cv A28/7) and after maximal leaf development (cv 049). Also, both slower rates of extended tuber bulking (cv

A28/7) and rapid rates of tuber bulking over a restricted period (cv 049) could lead to high yields in this species.

Reciprocal Grafts

Although estimation of light interception is directly related to the utilization of radiant energy for the synthesis of assimilate, it is not at all certain that the distribution of assimilate to tubers is similarly related to total dry matter production (e.g. the improvement of yield in Dutch winter wheat was achieved with reduction in total dry matter production; Table 14). The use of reciprocal graft experiments with high- and low-yielding cultivars could provide valuable information concerning whether the major yield limitation is in total assimilate production or in the capacity of tubers to accept, assimilate, as controlled by the process of tuberization. Such experiments (Wilson 1967; Hozyo and Park 1971) suggested that in sweet potato, the process of tuberization it-

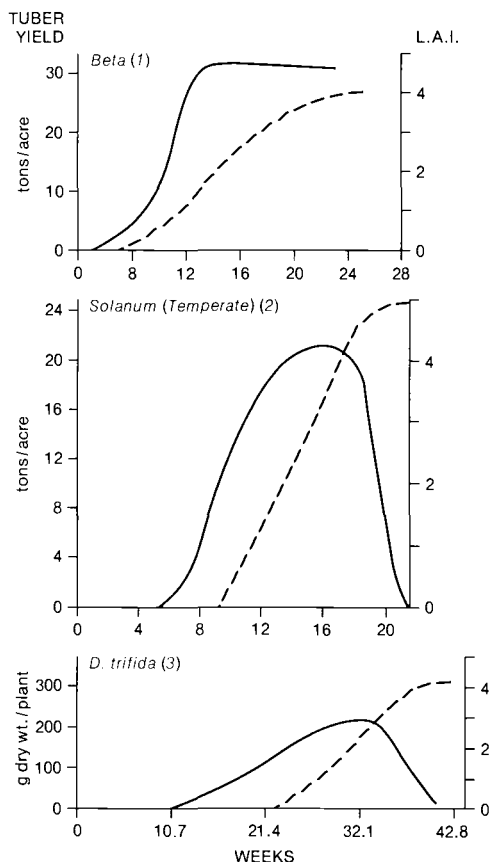


FIG. 4. Growth patterns of root crops adapted from Milthorpe 1967 (1), Radley 1963 (2), and Ferguson and Haynes 1968 (3).

self seems to be the more important determinant of tuber yield. This result is supported by the finding that increased tuber bulking increases the rate of photosynthesis in sweet potato (Spence and Humphries 1972). The reverse is apparently the case in cassava, since grafting experiments with *M. glaziovii* scions and *M. esculenta* root stocks used in the Mukibat domestic system of cassava production apparently results in cassava yields in the region of 100 tons/ha per year. Such yields are higher than the highest experimental yields recorded in *M. esculenta* (Table 7).

Tuberization

The potential importance of tuberization as a determinant of root crop yield necessitates

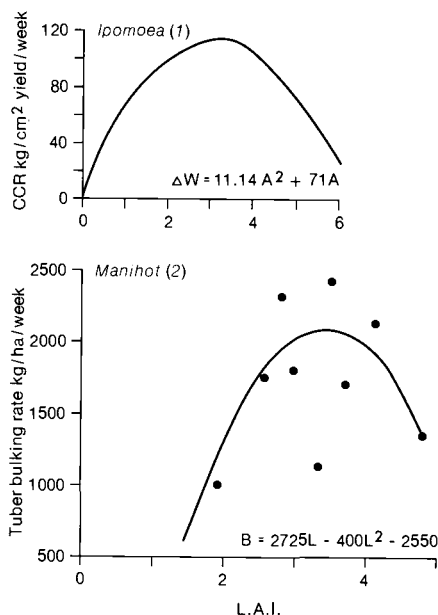


FIG. 5. Interrelationships between L.A.I. and growth rate adapted from Tsuno 1971 (1) and Enyi 1972 (2).

the development of technology for the elucidation of the sequential occurrence of events in this process. Studies on the anatomy of tuberization in sweet potato (Artschwager 1924; Togari 1950; Wilson and Lowe 1973) indicate that there are precise cellular events associated with tuberization. These include: (a) initiation of tuberization by the separation of protoxylem arms from a central lignified metaxylem cell through the development of a parenchymatous sheath; and (b) proliferation of storage parenchyma cells by the activity of the vascular cambium as well as secondary and tertiary meristematic strips.

It was further shown that the continuation of tuberization may depend on the capacity of these cells to generate storage parenchyma cells rather than lignified cells (Akita et al. 1962). These results make it possible to devise a system for the evaluation of the capacity for tuberization in individual sweet potato cultivars based on the cellular events related to this process. The finding that in the sweet potato, initiation ceases 8 weeks after planting in five cultivars studies (Lowe and Wilson

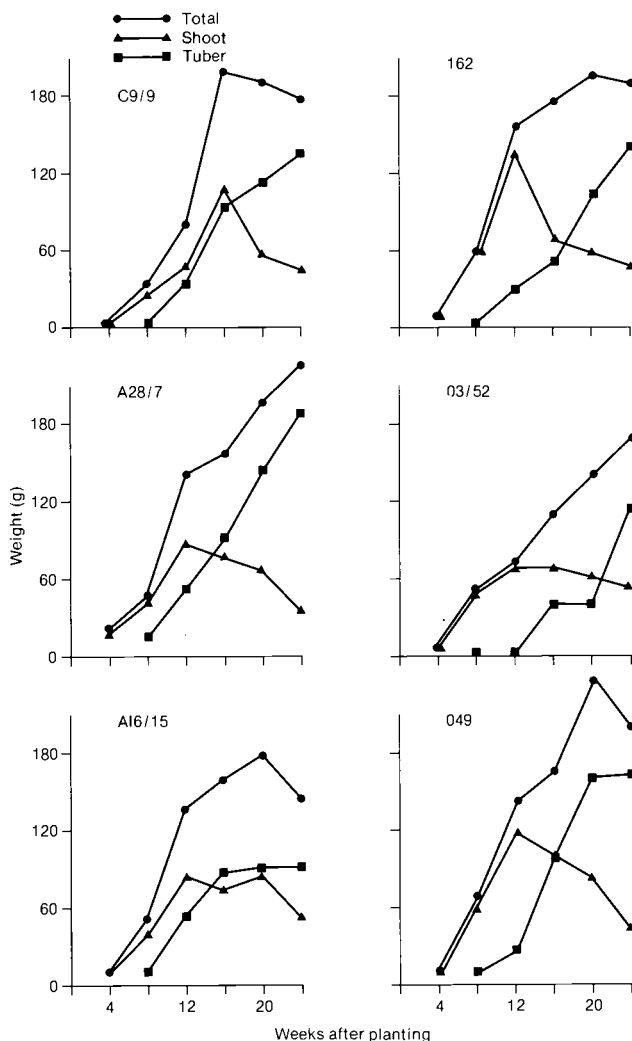


FIG. 6. Distribution of dry matter in six sweet potato cultivars (from Lowe and Wilson 1974).

1974) indicates the importance of early crop growth in determination of the final number of tubers per plant in this species (Fig. 7). Also, alternative root types with unrealized potential for tuberization (e.g. pencil roots, Togari 1950, and string roots, Wilson 1970) are produced instead of tubers in the course of sweet potato tuberization. Potential tuberization indices (alternative root types and tuberous roots) and percentage tuberization indices (tuberous roots as a percentage of all roots with a potential for tuberization, Fig. 8) show the increased propensity for formation

of alternative root types after the cessation of tuberization at week eight in six sweet potato cultivars studies. The existence of a negative correlation between tuber number and mean tuber weight (Fig. 9) suggests that, in addition, there is an optimal tuber number:tuber weight relationship for the realization of maximal yield potential of this species. Tuber shape (Lowe and Wilson 1974) is also an important consideration for development of cultivars suitable for mechanical harvesting.

The enzymes starch synthetase (Murata and Akazawa 1968) and phosphoglucumutase

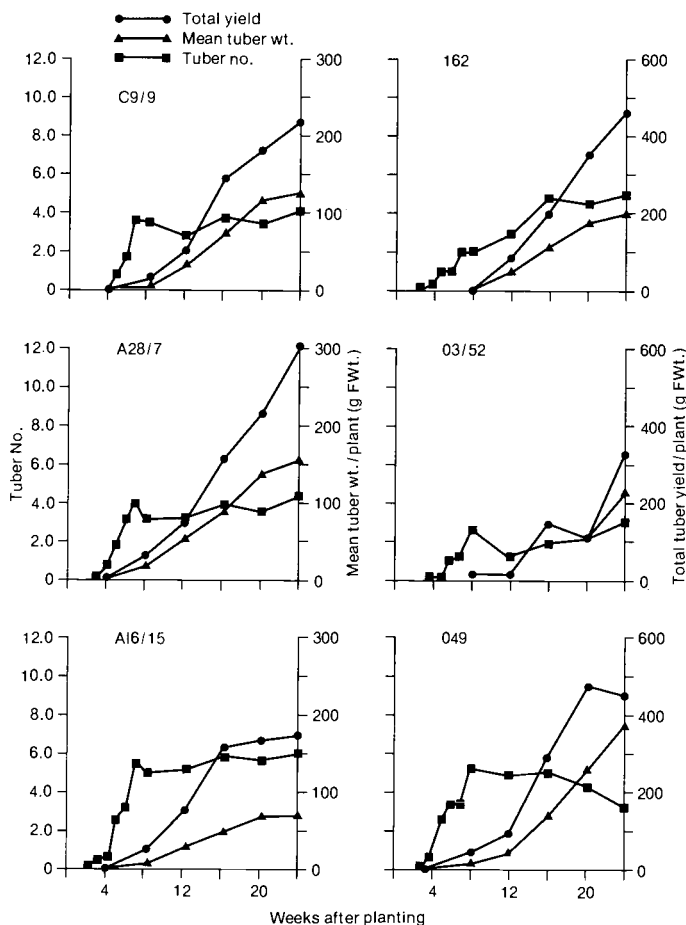


FIG. 7. Tuber number, mean tuber weight, and yield of six sweet potato cultivars (from Lowe and Wilson 1974).

(Napdal et al. 1971) have also been mentioned as determinants of the capacity for tuber bulking in sweet potato. Whilst the inverse relationship between generation of lignified cells versus storage parenchymatous cells might be explained by fluctuation in the activity of peroxidase and IAA oxidase enzymes (Akita et al. 1962; Sirju and Wilson 1974).

Photosynthesis

The case for increasing the rate of the process of photosynthesis in root crops is based on the following evidence: (a) existence of crop plants (e.g. maize) with C_4 photosynthetic pathways resulting in higher rates of

photosynthesis ($70 \text{ mg CO}_2 \text{ fixed/h/dm}^2$) compared with most crop plants and all root crops, with C_3 pathways, which have lower photosynthetic rates (i.e. $15\text{--}35 \text{ mg CO}_2 \text{ fixed/hour/dm}^2$); (b) higher growth rates and productivity of C_4 plants; and (c) the evidence that increased CO_2 concentration increases rate of photosynthesis, growth and dry matter accumulation in C_3 plants (e.g. in tobacco, Heskett 1963, and sugar beet, Ford and Thorne 1967). The evidence that increased photosynthetic rates produced increased shoot:root ratios in sugar beet (Ford and Thorne 1967) must mean that increased rates of photosynthesis will not necessarily result in increased tuber yields in root crops.

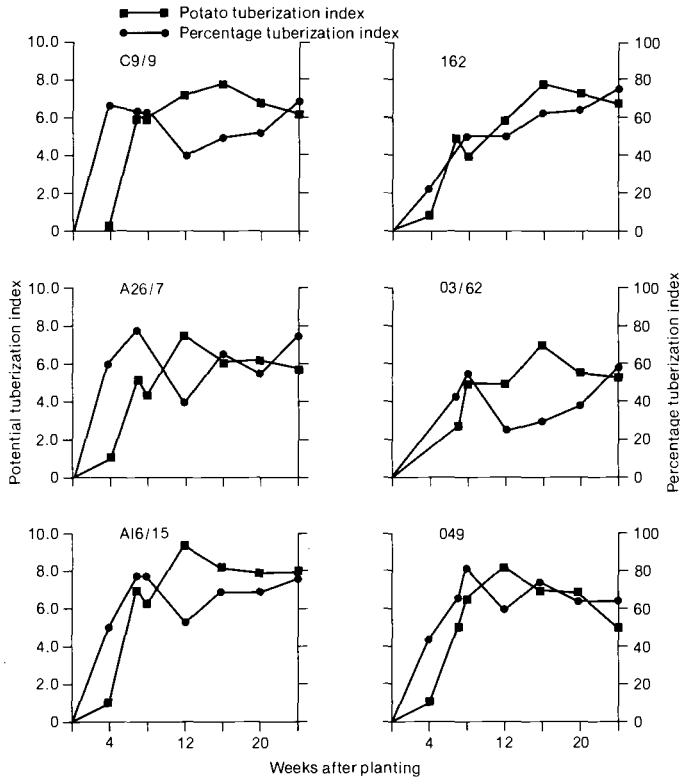


FIG. 8. Tuberization indices in six sweet potato cultivars (from Lowe and Wilson 1974).

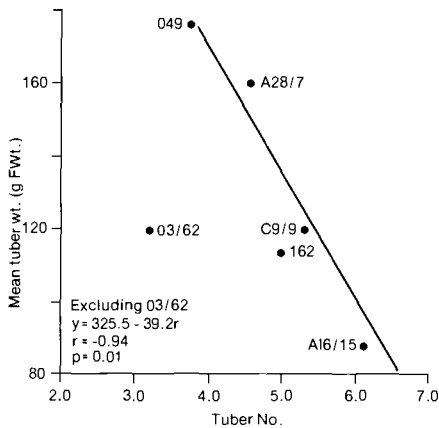


FIG. 9. Relationship between tuber number and tuber weight in six sweet potato cultivars (from Lowe and Wilson 1974).

However, the hybridization of cultivars with high photosynthetic rate with those with high capacity for tuberization might result in progeny with increased tuber productivity.

Technologies available for screening root crop cultivars for C_4 metabolism include (a) the Moss closed chamber technique and (b) screening for low CO_2 compensation points. Screening of sweet potato cultivars by the Moss technique has been initiated at IITA (Sadik 1973).

Nitrate Reduction

Nitrate reductase activity is known to be the rate-limiting step in protein synthesis (Beevers and Hageman 1969) and has been suggested as a breeding criterion for maize improvement (Hageman et al. 1967). The significance of the enzyme nitrate reductase in root crops is its possible relationship to rapid early growth of root crop species. Such rapid early growth

will result in shortening the time to closed canopy (e.g. in yams). Screening for nitrate reductase activity in sweet potato has indeed shown that rapid shoot growth tends to be correlated with high nitrate reductase activity (Wilson and Knox 1970). However, it will be necessary to find or to produce a cultivar in which nitrate reductase activity decreases either at optimal LAI (3 approximately) or during the linear phase of tuber bulking to release fixed carbon which might otherwise be used for amino acid and protein synthesis in leaves, for carbohydrate storage in tubers. Nevertheless, the slow rate of senescence of sweet potato leaves during the stage of maximal tuber bulking prior to harvest (Fig. 3) is associated with the maintenance of relatively high levels of nitrate reductase at harvest in this species.

Screening for nitrate reductase during early growth and leaf senescence might be done by the *in vivo*, leaf disc method developed by Klepper et al. (1971).

Rooted Leaves

Wilson (1967) referred to the rooted leaf as a "phytmodel," since it represented in miniature a photosynthetic surface, a translocation pathway and assimilate storage in roots. Such a model is therefore suitable for studying a number of physiological processes in root crops, especially when it is necessary to separate effects related to an individual leaf rather than effects associated with the entire plant or the crop community. Rooted leaves of sweet potato (Spence 1971) and cassava (de Bruijn 1971; Duncan 1974) produce tubers. Attention is, here, drawn. This technique is useful for rapid screening of large numbers of cultivars of these crops for disease resistance (leaf root and tuber), rate of photosynthesis, capacity for tuberization, and nitrate reductase activity. The method is also a useful tool for conducting basic studies on these and other aspects of root crop improvement (e.g. production of non-chimeral mutants for mutagenic breeding; Wilson and Lowe 1973).

To summarize the limitations to yield potential, improvement might be investigated by

the following (a) growth analysis; (b) reciprocal graft experiments; (c) cellular and sub-cellular investigation of tuberization; (d) photosynthesis measurement; (e) nitrate reductase measurement; and (f) rooted leaf screening. Results from such experiments would provide adequate information for the exclusion of the physiological limitations to yield, in breeding programs, to produce superior cultivars with high yield potential. The maintenance or incorporation of resistance to pests and diseases in such cultivars will then complete the synthesis of the elite root crop cultivars of the future. Attention is drawn to the multidisciplinary nature of the technologies involved and hence the desirability for establishing equally multidisciplinary teams of research workers to conduct experimentation on root crop improvement.

Controlled Hybridizations

Of the root crops considered for improvement of yield potential, *Ipomoea batatas*, *Manihot esculenta* and *Dioscorea trifida* and *D. rotundata* (Sadik 1973 personal communication) produce flowers and set fertile seed and can, therefore, be subjected to controlled hybridizations. However, there are incompatibility problems in *I. batatas* and not all cultivars of *M. esculenta*, *D. trifida* and *D. rotundata* produce flowers and fertile seed. In addition, other yam species, and *Colocasia* and *Xanthosoma* species are poor producers of flowers, and hence extensive breeding programs in these species would necessitate intensive studies on the induction of flowering. Alternatively, mutagenic breeding techniques may also be considered.

One of the most urgent requirements for root crop improvement is the initiation of investigations on the floral biology, including methods of flower stimulation, in root crop species.

Elite Root Crop Cultivars

No predictions are made on the vegetative habit of elite root crop cultivars of the future because high-yielding cultivars with different

vegetative habits will emerge. Accordingly, the selection of cultivars for cultivation would depend on a number of agronomic factors as well as on the system of cultivation desired (e.g.: (1) intensity of cultivation (spacing); (2) capitalization of cultivation for herbicides, insecticides, fungicides and land preparation; (3) availability of facilities for mechanical harvesting; and (4) large-scale vs small-scale cultivation. It should be the aim of root crop improvement to supply high-yielding cultivars suitable for the needs of different systems of root crop cultivation.

Improvement in the Utilization of Root Crops

The relatively high water content of root crop tubers is probably the major drawback in improving the utilization potential of these crops. Such high water contents lead to problems of tuber storage as well as tuber dehydration prior to subsequent processing. This apparent shortcoming of root crops may indeed be made into an advantage by the development of methods of utilization specific for root crop processing, rather than attempting to adapt temperate cereal technology for the utilization of root crops grown in the tropics. In this discussion of methods of utilization of tropical root crops, the following aspects of utilization will be briefly considered: (1) utilization of fresh tubers; (2) utilization of manufactured root crop products; (3) utilization of root crop foliage; (4) root crop dehydration; and (5) industrial utilization. Attention will be given both to current methods of utilization as well as to methods which might be developed in the future. Utilization for human food and for livestock feeds is also discussed.

Utilization of Fresh Tubers

There are three problems in the utilization of fresh root crop tubers as human food: (1) the inherently short post-harvest shelf-life of root crop tubers; (2) high ambient temperatures in the tropics which tend to further shorten shelf-life of tubers; and (3) poor quality of many root crop tubers.

In their inherently short post-harvest shelf-life, root crop tubers are adapted for almost immediate cultivation after harvesting, except in yams, in which the relatively short dormancy period may be broken by 2-chloroethanol treatment (Cibes and Adsuar 1966). This adaptation may be turned into an advantage in tropical climates by the development of cultivars suitable for continuous cultivation during a calendar year, thus extending the availability of freshly harvested tubers. Such an approach to increasing the availability of root crops is better suited to crops with short crop growth cycles (e.g. sweet potato). Heavy rains of the tropics also result in problems of cultivation, tuberization and harvesting. These problems can, however, be overcome by the use of different root crop species (e.g. taro) for rainy season cultivation.

Attention is drawn to the value of curing root crop tubers by exposure to high temperatures and humidity, easily obtainable under tropical conditions, as a method of increasing shelf-life of fresh tubers and reducing the incidence of storage diseases.

Although use may be made of tubers unsuitable or unacceptable for human consumption or livestock feeds, the development of livestock feed industries based on root crops necessitates methods that allow for more permanent storage than that allowed by fresh tuber utilization.

There is no doubt that storage at lower temperatures will increase the shelf-life of root crop tubers. It is, however, doubtful whether the cost of refrigeration, which will undoubtedly be passed on to the consumer, can be justified in many tropical countries. All year-round production or future development of cultivars with extended dormancy of tubers adapted to storage at high temperatures seem to be better alternative solutions to the problem of high tropical temperatures. The two approaches can be made compatible by the use of dormancy-breaking devices for immediate cultivation after harvesting in tubers with increased shelf-life dormancy.

Except perhaps in sweet potato, root crop tubers have not been systematically selected for improved tuber quality. Such selection

will increase the acceptability of root crops particularly to the urban communities of tropical countries. Some aspects of quality relevant to root crop tubers are shown in Table 17. These parameters of tuber quality should be included in the screening process for the development of high-yielding cultivars of tropical root crops.

Manufacture of Processed End Products

HUMAN CONSUMPTION

Except in Japan, and perhaps in some South American countries where sweet potato and cassava tubers, respectively, have been used as a source of industrial starch, processing of root crops is viewed as a method of extending the availability of the commodity for human consumption. The production of the cassava product “gari” in West Africa and the taro product “poi” in Hawaii are examples of such processing of root crop tubers. Perhaps the greatest problem in the improvement of range of root crop tuber products is the relatively low production of root crop tubers in many tropical countries, which together with high demands for tubers by local populations, lead to increased prices of fresh tubers, beyond the limits of feasibility for processing. These characteristics of root crop production have frustrated the efforts of at least two South American countries which sought to improve cassava product utilization by legaliz-

ing the inclusion of relatively low percentages of cassava flour in wheat flour, for bread manufacture. A major solution to the problems of root crop tuber processing is, therefore, the increase in production and productivity of root crop cultivation as well as the yield potential of root crop cultivars.

Assuming availability of a regular supply of low-priced root crop tubers on which to base processing industries, perhaps the most urgent processing problem inherent in tubers is their high water content. Solution of this problem depends on the development of efficient methods of dehydration. Such methods might be made more economically viable by the development of by-products from root crop dehydration. Accordingly, the expression of water together with soluble tuber constituents by crushing, prior to dehydration might provide a substrate for single-cell protein industries. In turn, the development of protein as a by-product of root crop dehydration might solve the high cost of protein fortification of products made from root crop flours (e.g. from soya, peanut and fish products).

Root Crop Flours Once viable root crop flour industries are developed, preliminary experimentation has shown that such flours can be used either together with wheat flour or indeed alone, for the manufacture of a range of bread and pastry products. It has also been shown that fresh cooked yam tubers can be

TABLE 17. Some parameters of quality in tropical root crop tubers.

Quality parameters	Tuber characteristic for improvement
(1) Wastage on cooking	Development of thinner tuber skins adaptable to easy peeling Reduction of incidence of storage diseases Increasing shelf-life and reducing advent of changes associated with germination
(2) Eating quality	
Colour	Reduction of darkening — polyphenol and anthocyanin contents of tubers
Texture	Starch grain and cell size of tubers Occurrence of lignified cells
Taste	Identification and improving flavour components of tropical root crops
Nutritional quality	Maintenance and improvement of vitamin content of root crop tubers in breeding programs for high yield

used together with wheat flour for bread manufacture (Kawakami 1970). Manufacture of bread and pastry products with composite flours, including root crop flour, has been reported for sweet potato and yam flour (Sammy 1970, 1973) and cassava flour (Kim and de Ruiter 1969; Chatelanat 1970).

Fermented Products Recently there have been serious attempts to commercialize the manufacture of West African "gari." A mechanized continuous gari manufacturing plant has been reported by Purcell and Williams (1973) for large-scale production of gari. Also the development of machines which make gari production a profitable rural industry has been reported by Wadwa (1973). No such developments in the manufacture of the Hawaiian "poi" are known to me.

New Products Perhaps the most promising new root crop product is the instant dehydrated yam developed at the University of the West Indies by Steele and Sammy (1973). The product has been carried to the pilot stage by the Agricultural Development Corporation of Barbados (W.I.) and is now being test marketed in the Caribbean, Europe and North America.

A breakfast food in the form of flakes is also being developed by Sammy and preliminary products of good quality have been produced.

Infant Foods There is a good case for the development of infant foods from arrowroot (*Canna edulis*) starch which has long been produced in the island of St. Vincent, W.I., and has had the reputation of being highly digestible. Clinical studies on the suitability of "poi" for normal, allergic and potentially allergic babies (Glaser et al. 1965) seem to warrant the development of infant food products from taro.

Protein Content of Root Crop Flours Although on a fresh weight basis the quantity of protein in root crop tubers appears to be low, dehydration of root crop tubers to produce flour leads to protein contents which compare favourably with other crops on a dry weight

basis. Also, analysis of utilizable protein improves the position of root crops relevant to these crops (Payne 1969; Table 18).

LIVESTOCK FEEDS

Strangely, the utilization of root crops for livestock feeds is probably more extensive in Europe, where considerable quantities of dehydrated cassava chips or pellets are imported from Thailand and West Africa, despite a chronic shortage of protein in many tropical countries. Clearly, methodology exists for the utilization of at least cassava in livestock feeding, which could be immediately applied to improving the availability of meat protein in tropical countries.

Use of other root crops as livestock feeds has not been developed to the extent of cassava, but there seem to be few inherent problems in such developments. However, the use of uncooked dehydrated yams in rat feeding trials has resulted in caecal enlargement and sometimes projectile defaecation (Unsworth 1973 private communication). This syndrome disappears when yams are cooked (Unsworth 1973 private communication). Problems involved with the utilization of root crops for livestock feeds are being examined in the University of the West Indies.

Utilization of Root Crop Foliage

Utilization of the high protein content root crop foliage both for human food and livestock feeds is a subject that has, as yet, not

TABLE 18. Utilizable protein in some staple foods.

	Protein calories, %	Utilizable protein, %
Sago	0.6	0.3
Cassava	1.8	0.9
Plantain	3.1	1.6
Yam	7.7	4.6
Maize	11.0	4.7
Rice	9.0	4.9
Potato	10.0	5.9
Wheat	13.4	5.9

^aFrom Payne 1969.

been fully investigated. However, traditional methods of utilization of the leaves of taro for soups in the Caribbean, and cassava leaves as a spinach in West Africa, indicate the value of traditional methods of utilization as a base for modern processing industries. A soup made from taro leaves together with okra fruit (callaloo) enjoys the status of a national dish and has been commercially produced by canning in Trinidad.

Developments in Root Crop Dehydration

Sun drying of chipped root crop tubers is practised both in Asia and in Latin America with considerable efficiency. More recently, the parameters involved in the use of solar energy for sun drying have been investigated by Rao (1973) and solar driers for dehydrating of root crop tubers for use in livestock rations have been developed at the University of the West Indies by Headley and Springer (1972).

Industrial Utilization

Sweet potato is used for industrial starch manufacture in Japan. The proportion of the crop used for starch manufacture increased from less than 10% in 1936 to approximately 50% in 1968 (Fujise 1970). Largely responsible for this increase was the production of cultivars with higher starch contents. The advantage of the trailing sweet potato habit against typhoons compared with say maize is of considerable importance in Japan and in other countries susceptible to inclement weather. Approximately 10% of the Japanese sweet potato crop was used in the manufacture of sake and alcohol in Japan in 1968 (Fujise 1970).

The high starch content of its tubers has made cassava an important source of industrial starch in tropical countries. However, starch manufacturing industries tend to suffer from low supply of tubers because of the demand for cassava for human consumption.

Conclusion

I have tried to emphasize the considerable need for more intensive research investiga-

tions in tropical root crops. Research should be organized on the basis of integrated research programs including aspects of both production and utilization. In the University of the West Indies, such a research program has been made possible by collaboration between faculties of agriculture, natural science and engineering. The program has been in existence since 1967 with support first from the Rockefeller Foundation and more recently from the International Development Research Centre, and this approach to root crop research was reported by Haynes (1970). Such an integrated approach to investigations on root crops is recommended to both national and international institutions currently involved in root crop improvement.

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Intensification of Cropping Systems in Asia

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Abstract The intensification of land and labour utilization through improved cropping systems is a promising alternative for increasing food production and employment in rural Asia, the sector where the problems of low income and malnutrition are most acute. While various types of cropping patterns are practiced in the region, however, the intensity of land use in most cultivated areas remains low.

Experience in the Philippines, where the adoption of improved cropping is being accelerated in several pilot communities, indicate that the majority of small rural farmers are willing to take the risk of added cash and labour inputs provided credit is available and markets for their products are assured. Unfortunately, these requirements are not easy to satisfy. It would seem, therefore, that a major task for the successful adoption of intensive cropping in Asia is the establishment of socioeconomic structures that would improve credit and marketing facilities in the rural sector.

Résumé L'intensification de l'utilisation de la terre et de la main-d'oeuvre, grâce à l'amélioration des systèmes de culture, constitue une possibilité prometteuse d'accroissement de la production alimentaire et d'élargissement du marché de l'emploi dans le monde rural asiatique. Ce secteur est celui où les problèmes de malnutrition et d'insuffisance des revenus sont les plus aigus. Bien que de nombreux types de modes de culture soient mis en oeuvre dans cette région, la terre y est encore cultivée en de nombreux endroits d'une manière peu intensive.

Selon l'expérience tentée aux Philippines, où l'on s'efforce d'accélérer, dans un certain nombre de collectivités pilotes, l'adoption de techniques culturales meilleures, il semble que la majorité des petits agriculteurs acceptent le risque d'augmenter leurs apports en espèces ou en main-d'oeuvre, à condition de trouver du crédit et de bénéficier de garanties pour l'écoulement de leurs produits. Il n'est malheureusement pas facile de répondre à de telles exigences. Il semblerait par conséquent que l'un des facteurs essentiels de la réussite en Asie de l'adoption de méthodes de culture intensive soit la mise en place de structures socio-économiques améliorant le crédit et les circuits de commercialisation du secteur rural.

Introduction

A major alternative for increasing crop production in Asia is the intensification of land

and labour utilization on areas that are presently under cultivation. This can be achieved by increasing the number of crops or the number of days in which an area is put to pro-

ductive use through any of the following techniques: *Multiple Cropping* — the growing of more than one crop in the same land in one year (Harwood and Banta 1973) where only pure stands are sown at any one time (Dalrymple 1972); *Intercropping* — the growing of two or more crops simultaneously in the same area; and *Relay Planting* — the interplanting of seeds or seedlings in between plants of a maturing annual crop.

In this paper, I shall try to look at the potentials of improved cropping systems in Asia, the extent of their adoption in the region, and our experience in introducing multiple cropping in selected communities in the Philip-pines.

Prospects of Intensifying Cropping Systems in Asia

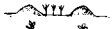
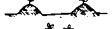
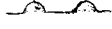
Most of the developing countries of Asia have a tropical or subtropical climate and can grow crops at any time of the year provided water is available. Experiments by Bradfield (1970) at the International Rice Research Institute (IRRI) shows that five crops including a crop of rice can be harvested from the same area in 1 year (Table 1). Luh (1969) reports that as many as nine crops a year are raised by vegetable growers in Hong Kong and Viet-nam. Harwood and his group have shown that weeds and insect incidence can be reduced by intercropping. The combination of corn and mung, for example, not only gives high yield but has a distinct advantage for weed control. The combination of peanut and corn markedly decreased borer damage in corn.

A major limiting factor for intensive crop-

ping in Asia is water. More than 50% of arable lands grown to annual crops depend on rainfall. Since precipitation is not distributed evenly throughout the year, many farmers grow rice during the monsoon season and leave the land idle during the dry months. Ex-periments at IRRI and UPLB have consistently shown that, in areas with 6-8 months of rain-fall, another crop after rice can be grown without additional irrigation. The technique is to prepare the land before the rain comes instead of the usual procedure of waiting for the land to be submerged in water before plowing. This technique allows for the plant-ing of rice right after the first rain instead of 45-60 days later. This time saving is enough to mature a crop of rice so that corn, vege-table or even rice can be grown before the dry months come.

Considering the fact that land is a very scarce resource, that farm labour is abundant, and that the majority of the low-income group is in the rural sector, the intensification of cropping systems in Asia is very attractive. The labour absorption of a unit area of land can easily double by the addition of another crop where only one was planted before. Fur-thermore, the benefits from intensive land use do not discriminate against, and may even favour, the small landowners. Indeed, the prospects of improved cropping systems are so bright that it has been referred to as a means toward a more successful utilization of the Green Revolution, the labour intensive tech-nology that could bring most subsistence farm-ers into the stream of market-oriented econ-omy, and the technology that could solve the serious nutrition problems among the rural poor.

TABLE 1. A one-year cropping sequence for rice and four other crops (Bradfield 1970).

Crops	Days to harvest	Tillage operation
Rice	102	
Sweet potato	100	
Soybeans	85	
Sweet corn	66	
Soybeans (green)	60	

Cropping Systems in Southeast Asia

While the practice of growing several crops in the same area has an ancient history in Asia, the extent of its practice has been far from impressive. In a review of country data, Dalrymple (1973) shows that many countries in the region, especially in Southeast Asia, have a low cropping index (Table 2). Aside

TABLE 2. Intensity of cropping systems of Asia (Dalrymple 1973).

Country	Period	Multi-cropped area (1000 acres)	Cropping index
Burma	1965-66	2,162	111.1
Bangladesh	1968-69	8,479	119.2
India	1966-67	48,456	114.4
Indonesia	1964	5,248	126.2
Japan	1967	3,672	126.0
South Korea	1969	3,074	153.4
Pakistan	1967-68	3,046	108.5
Philippines	1960	4,982	136.0
Taiwan	1969	1,905	184.3
South Vietnam	1960	621	112.5

from traditional social barriers two major reasons can be cited: 1) difficulty in transmitting the technology, and 2) lack of socio-economic structures to support the technology.

While the technology for the culture of a single crop may be easy to transmit to farmers, the techniques for intensifying cropping systems involve not only changes in managing familiar crops, but also new crops which may be totally unfamiliar to a farmer. Furthermore, intensive cropping systems require more labour, more capital and a better marketing system. Inadequacy in any of these could easily lead to the failure of the whole system. Many farming communities in Asia lack many of the social infrastructures that promote a market-oriented economy. Transportation from farm to market is difficult. Credit is non-existent in many cases. As a consequence, if several crops are grown on one farm the motivation is for consumption within the family or small community instead of the market outside.

In spite of the low level of adoption, a wide range of cropping systems is practiced in the region. Three common systems are reviewed.

Systems built around rice

Rice is the most important staple crop of Asia and occupies the largest area devoted to

any one crop. When water is readily available, the most common system of cropping is the monoculture of rice. Two to three crops are grown within a 12-month period with the highest yield usually obtained during the dry months. This system is competitive since rice is a prestige crop and the grain is the most salable commodity on the farm. Furthermore, since rice is usually grown under flooded conditions, such areas are not easy to cultivate for other crops within short intervals.

Only a small portion of farms in Southeast Asia, however, have sufficient water to satisfy the requirement of flooded rice year round. In fact, more than 50% of the rice-growing areas depend primarily on rain for water. In these areas rice is grown during the monsoon months when rain is most abundant and the land is either planted to other crops or left idle after the rice crop. Some of the major crops grown after rice are corn, sorghum, pulses and vegetables. The major problems with these systems are: 1) Although rice takes only 4 months to mature, it takes 2-3 months of rain before enough water is accumulated in the paddy for traditional rice culture; 2) Puddled soils are not easy to convert to upland crop culture; 3) Crops other than rice are not as easily marketed; and 4) Difficulties in water management.

Systems involving annual crops other than rice

The system of cropping in these areas differs from those with rice primarily in terms of cultivation. The land is prepared dry and at no time is the land submerged in water. This management practice is common to many crops and consequently a wide range of cropping systems are practiced. The major factors affecting the choice of crops are market opportunities, storability of a crop, and tolerance to water stress.

As a general rule, the high-profit crops such as tomatoes, eggplant and other vegetables, which are also high-risk and labour-intensive, are grown in areas near market and population centres. In contrast the grain crops such as corn, sorghum and pulses are grown in less accessible areas.

Systems involving perennial tree crops

One of the most important perennial crops in the Philippines is coconut. Plantations of this crop extend from areas near metropolitan Manila to as far south as Mindanao. Because of the morphology of coconut many plantations near populations centres utilize the area between the rows for other crops. One of the most intensive is the cultivation of papaya and pineapple, a system that increases the profits from the land by more than 100%. Bananas, lanzones and such root crops as gabi and sweet potatoes are also used extensively.

Introduction of Multiple Cropping in Selected Communities

With the wealth of information on cropping systems from the experiment stations and commercial farms, the UPLB in cooperation with IRRI and IDRC started a project in 1973 whose primary objective is to improve the cropping systems in selected communities in the Philippines. By working on pilot communities, instead of with individual farmers, we hope to: 1) develop workable patterns of introducing intensive cropping to rural farmers; 2) identify the social and economic problems in the adoption of the technology; and 3) assess the social and economic impact of the technology.

The pilot communities

The smallest unit of formal government in the Philippines is called a barrio. It is formally headed by a barrio captain and a council of about 5–7 barrio leaders. A typical barrio is about 200 ha in area with about 150 households. This is the type of community which was used as a unit for the present project.

Since the project covers only six barrios, it was necessary to limit the types of communities that we should work with. We therefore decided to limit our choice to those that satisfy two features: first that rice is a major crop and adequate water for rice irrigation is available only during the monsoon months (about 60% of our rice farms belong in this category); secondly, the barrios must be accessible by road and not too far from market

outlets. We felt that this feature was necessary for a market-oriented cropping system. The specific features of the six barrios selected are shown in Table 3. Some of the general features are as follows: 1) source of water for the rice paddy comes from rain or irrigation canals which supply adequate water during the monsoon months but not during the dry months; 2) the barrios are near the population centres and market outlets; 3) population density is high and landholding is small; 4) average income per household is small and food intake of young children is below the normal requirement; 5) alternative job opportunities aside from farming are available; and 6) farm equipment consists primarily of farm animals and hand tools.

Introduction of multiple cropping in the barrios

Since the ultimate objective of the project is to introduce multiple cropping in the barrios, to the extent that the technology will continually be adopted even after the project is phased out, our strategy was based on the following guidelines: 1) that only technical advice will be given free. All material inputs will have to be paid by the farmers at cost; 2) that our entrance activities should try to

TABLE 3. Some characteristics of the pilot communities (average of six).

No. of households	418
Size of household	6.4
Income per household (\$/year)	395
Education (years in school)	4.7
Nutritional status (% of normal)	
Children's height	90
Children's weight	79
Food consumption (kg/day)	4.2(2.2)
Land area (ha)	292
Farm size	1.9
Percent owned	23
Farm animals and implements	
Work animals	112
Animal-drawn cultivators	119
Hand tools	508
Hand sprayer	22
Power machinery	2

use and strengthen existing barrio organization and services where they exist; and 3) that the project should provide other additional inputs and services at the start, with the intention that they be taken over by the local residents as soon as possible.

Each barrio is assigned one technician who is a BSA graduate with training in multiple cropping. The technicians reside and work full-time in the barrio. The technicians were fielded in their respective barrios in June 1972. At this time, the rice field is being prepared for planting. The first task of the technician was to assist the farmer in rice culture and at the same time encourage farm families to plant other crops in their backyard areas. The backyard planting was very effective in illustrating the technology and profitability of growing other crops as well as rice. When rice was ready for harvest many of the backyard crops were also being harvested and the farmers had a good basis for deciding whether they will try the same crops in larger areas utilizing the rice field which would otherwise be idle. By the end of the first year at least 5% of the rice paddy was already planted with a second crop.

In most cases during the initial planting of other crops, the farmers were not ready to cope with the additional needs of the more capital-intensive and more perishable nature of the new crops. In many cases our technicians helped in facilitating bank loans, procurement of seeds, fertilizers and other inputs, and later in locating and transporting their produce to market outlets. All these services, however, were paid by the farmers. At the same time these activities gave the technicians a good opportunity to illustrate to the farmers the problems, the expertise and the services that they will have to contend with in the new cropping system.

By the end of the first year, many farmers were convinced of the profit potential of growing other crops after rice. They were also aware of the need for services that were initially provided by the technicians. This awareness was the source of motivation for the farmers to organize themselves into groups that can share the needed services. At this time,

it became necessary to organize the skeletal structure of a barrio farmers organization. It is our intention to strengthen these organizations and make them functional before the end of 1973. The area to be devoted to multiple cropping is expected to increase threefold in 1973 and, consequently, more supporting services will be needed. This barrio organization will be put to the test in 1973. Although the technician will continue to play a key role, we hope that this leadership can be eventually transferred to the local leaders of the newly formed organization.

Impact of Multiple Cropping

Cost and returns

Our objective during the first year was to reach a few strategic farmers in the barrio with the hope that these few would succeed and serve as example to others. In terms of area, this initial target is less than 5% of the whole pilot barrio, so I will not attempt to evaluate its impact on the whole barrio.

Among the initial target farmers, we keep records of their daily activities in terms of cash, labour and other inputs together with the cash and non-cash farm income (Table 4). The data show that: 1) some crops such as tomato, eggplant, cabbage and watermelon, aside from having high profit potential, need intensive labour per unit area resulting in a good potential for absorbing excess labour in the farm; 2) a wide variety of crops can be grown after rice with good profit potential as long as adequate water is provided. For many crops included in Table 4 water was provided from shallow wells and manually hauled to the field. We are now looking at small manual pumps that may be used to simplify this task; 3) the success of most of the initial farmers has shown that profit and labour absorption per unit area per year can be easily doubled by planting another crop after rice. Present indications are that these attractive possibilities will at least increase the area participating in double cropping to at least four times that of last year; and 4) together with the planting of an additional crop after rice is the introduc-

TABLE 4. Cost and returns per hectare for some selected crops.

Crop	No. of farmers	Area planted (ha)	Man-days per crop	Total expenses (P)	Net Income (P)
Rice	35	51.40	123	1714	92 ^a
Corn	16	8.93	48	589	184
Watermelon	26	4.90	180	1901	1616
Tomato	32	4.36	308	2574	5402
Cucumber	21	2.75	202	1636	438
Beans	27	2.66	136	1439	520
Mung bean	8	0.92	235	1917	559
Eggplant	10	0.66	269	1490	5036
Cabbage	8	0.30	292	2685	4687

^aAbout 60% of the area was heavily infested by tungro, hopper burns and/or grass stunt. The average income in the healthy areas is P831.

tion of improved varieties for many kinds of crop species such as watermelon, cucumber, beans, tomato, cabbage, eggplant, and sweet potato.

Use of credit facilities

As mentioned previously, credit to the pilot communities was liberalized through the use of added collateral provided by the project to the nearby rural banks. By early 1973, 186 farmers had used this facility with total loans of a little less than \$10,000. As expected many farmers participated but, more important, the number of defaulting borrowers is small. Our observation is that when the crop succeeds the farmers are very willing to repay their loans.

Establishment of supportive socioeconomic institution

After 1 year of demonstrating the profitability of multiple cropping and discussing with individuals and groups enthusiasts the problems involved in establishing an on-going multiple cropping enterprise in their community, some cooperators and assisted farmers decided to organize themselves into a multiple cropping farmer association (MCFA). The membership of the association is Bilogbilog 30, Marinig 38, Baclaran-Gulod 34, Bagong Pook 22, Bagumbayan 35, and Callos 20.

These associations are newly organized and their activities will centre on cooperative borrowing, procurement and marketing of farm inputs and products.

Future Plans

1 We are expanding our record-keeping activities from the 10-ha area reported here to approximately 120 ha involving about 200 farmers.

2 We have now encouraged some farmers to plant and harvest from the same area three times in one year.

3 We are increasing our pilot areas from 6 to 12 with the new areas located in provinces that are less populated and less accessible than those presently described. These new pilot areas are more typical of farmlands farther away from metropolitan Manila.

4 In all these pilot areas we project a 4–5-year stay in each barrio. Within this period we expect the barrio to have had enough experience in multiple cropping to continue on without the help of the project.

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SESSION III PAPERS

Quality Control and Processing

Tan Eng Liang, Chairman



Cereal Quality Control Program at the Centro Internacional de Mejoramiento de Maíz y Trigo

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Abstract Plant breeding to develop new cultivars and to improve yield must be based on properly analyzed germ plasm to ensure crops of a high nutritional value. Screening techniques for protein, lysine, and tryptophan are described. The dye-binding capability (DBC) method of screening for protein content is also discussed as well as the need for establishing appropriate and efficient biological assays that can be used in the development of cereals with higher nutritional quality.

Résumé La phytosélection, dont le but est de créer de nouveaux cultivars et d'améliorer les rendements, doit être basée sur du matériel génétique soigneusement analysé et ce, afin de faire en sorte que les produits récoltés auront une valeur nutritive élevée. L'auteur décrit des techniques de recherche des teneurs en protéines, en lysine et en tryptophane. Il évoque également les méthodes de testage de fixation du colorant (TFC) afin de déterminer la teneur en protéines, et affirme le besoin de définition d'essais biologiques appropriés et efficaces que soient utilisables pour la création de variétés de céréales à valeur nutritive élevée.

As the human population increases in the world, the pressure for efficiency and higher productivity of agriculture will continue. Producing adequate quantities of highly nutritious food is even more demanding.

World food shortage continues despite the development of new technology capable of greatly increasing yields in certain crop cultivars, i.e. high-yielding varieties, proper fertilization practices, and control of diseases and pests.

In the developing countries 60–80% of the total population is tied to small plots of land in an inefficient, subsistence level of agricul-

ture. Therefore food and especially animal proteins are always in short supply and expensive, costing the average consumer 60–80% of his income in normal times, and when drought, floods or disease reduce the harvests, all of his earnings. Still the consumer is unable to buy what he needs. Most low-income people, both urban and rural, suffer protein-calorie malnutrition.

Protein Sources

Currently 71% of the world protein comes from plant sources and 29% from animal

sources (Table 1). Cereal grains represent approximately 50% of the plant protein supply, which is nearly four times greater than that supplied by either the pulses, oilseeds, and nuts, which constitute 13% of the total. The protein obtained from vegetables and fruits, and from starchy roots, represents 3 and 5%, respectively, of the human intake.

Among the animal proteins, meat and poultry are the most important sources, representing 13% of the human protein intake. Dairy products constitute 11% of the intake, followed by eggs and fish which represent 2 and 3% respectively.

Unfortunately a great disparity in distribution of the well-balanced animal proteins occurs between different countries of the world, and also between groups with different income levels within the same country.

Animal proteins are more expensive than plant proteins, so cereal grains are mainly eaten constituting the main source of dietary protein in developing countries. The reason for this dilemma becomes readily apparent when one considers the conversion factor required to transform cereal grains to animal proteins. It requires under good scientific management the following:

- (a) 2.5 kilos of cereal grain to produce 1 kilo of chicken meat.
- (b) 4.0 kilos of cereal grain to produce 1 kilo of egg.
- (c) 4.5 to 5.0 kilos of cereal grain to produce 1 kilo of pork.
- (d) 6.5 to 7.0 kilos of cereal grain to produce 1 kilo of prime beef.

The widespread bad weather and consequent low grain production for human and animal consumption in 1973 requires that we urgently

expand production of all our current major sources of proteins, and at the same time attempt to exploit certain new scientific discoveries that now appear promising.

Improving Amino Acid Balance of Cereal Proteins

In general, cereal proteins are deficient in one or more of the essential amino acids required in the diet of humans and monogastric animals. All are especially deficient in lysine, and maize is also deficient in tryptophan.

Maize

Maize protein quality is of primary importance for food and feed in many countries. Common maize is normally low in food value because of its low protein and unbalanced amino acid content.

The maize mutants opaque-2 and floury-2, whose superior protein quality was recognized in 1964, opened the door to new horizons in the improvement of the nutritive value of cereal proteins. The opaque-2 mutant maize contains more than double the levels of lysine and tryptophan present in normal maize Mertz et al. 1964 (Table 2).

Growth rates of rats and swine fed opaque-2 maize demonstrated the greatly superior protein quality of this mutant over normal maize (Mertz 1966; Pickett 1966). Children in advanced stages of protein-calorie-malnutrition were fed opaque-2 maize as the only source of protein and recovered spec-

TABLE 2. Content of protein, lysine, and tryptophan of normal maize and its Opaque-2 counterpart.

	Protein % (N $\times$ 6.25)	Tryptophan (g/100 g protein)	Lysine (g/100 g protein)
Tuxpeño Normal			
(W.K.)	10.22	0.65	2.45
(End.)	9.75	0.42	1.91
Tuxpeño-Opaque-2			
(W.K.)	10.75	1.00	4.08
(End.)	8.72	0.81	3.76

TABLE 1. Sources of protein in the human diet.

Animal sources		Vegetable sources	
	%		%
Meat	13	Grains	50
Dairy products	11	Pulses, oil seeds nuts	13
Eggs	2	Vegetables and fruits	3
Fish	3	Starchy roots	5
Total:	29		71

tacularly (Bressani et al. 1970; Pradilla et al. 1969).

However, the original opaque-2 maize had several agronomic shortcomings. The kernels were less dense than their normal counterparts which affected test weight, and yield was lower in most cases. Another drawback was the susceptibility to diseases and insect attack both in the field and on the stored grain. However, due to genetic variability in some populations of opaque-2 materials, there was a tremendous variation in the vitreousness of the kernel. The presence of varying degrees of vitreousness in the opaque-2 kernels results from the action of a number of modifying genes affecting the opaque-2 locus.

To learn more about the biochemical behaviour of these modifiers, hard and soft fractions of endosperm in different modified phenotype opaque-2 lines were analyzed sep-

arately for protein, tryptophan and lysine content (Table 3). Hard fractions of endosperm had a higher protein content. The percent of tryptophan and lysine in protein was higher in the soft fractions of opaque-2 than in the hard fractions. However, in some opaque-2 populations such as the Veracruz 181-Antigua Grupo I-Venezuela, no difference in lysine and tryptophan content has been observed between the opaque-2 and modified hard endosperm phenotypes. In fact, the modified type showed a slightly higher level. It would seem from the data in Table 4 that protein and amino acid content are influenced by a modifying gene complex and its action is different in different genetic backgrounds.

Therefore it has been clearly shown that through effective breeding and selection after chemical evaluation, it is quite possible to combine protein quality and desirable agronomic

TABLE 3. Protein, lysine, and tryptophan content in whole endosperm and in hard and soft fractions of the endosperm in modified phenotype Opaque-2 lines.

Line	% Protein ($N \times 6.25$)			% Tryptophan in protein			% Lysine in protein		
	End. fraction			End. fraction			End. fraction		
	Whole	Hard	Soft	Whole	Hard	Soft	Whole	Hard	Soft
Tropical Opaque-2 Composite	10.9	11.6	11.2	0.76	0.63	0.85	2.98	2.87	3.65
Pob. Crist. #1-	9.4	10.2	8.4	0.73	0.55	0.72	2.73	2.43	3.36
PD (MS) 6 Eto-Cuba 11 J	9.9	10.0	7.7	0.70	0.63	0.83	2.67	2.22	2.88

TABLE 4. Protein, tryptophan, and lysine content in the whole kernel of normal, Opaque-2 and modified phenotype of maize.

Sample	% Protein ($N \times 6.25$)	% Tryptophan in protein	% Lysine in protein
Veracruz 181			
Antigua Gpo. 1			
Venezuela			
Normal	10.50	0.63	2.54
Opaque-2	11.07	0.93	3.73
Soft phenotype			
Opaque-2	10.75	0.96	3.98
Hard or modified phenotype			

characteristics in such a way as to overcome the original drawbacks of high-quality maize.

Barley

In 1968, Swedish workers reported the first positive variation in amino acid composition in a primitive Ethiopian barley variety recovered from the World Barley Collection (Hagberg and Karlsson 1969; Munck 1971). Since the content of protein and lysine was high, the name "Hiproly" was suggested for this variety. Munck (1972) used experimental animals to prove the high nutritive value of this variety.

The recessive gene (lys) found in Hiproly controlling high lysine is being used in barley breeding programs in many countries in order to produce high nutritive barleys for feed and food. CIMMYT's research group is interested in using this gene to develop naked high-yielding barley varieties with high nutritive value. They would be used for human food in low rainfall areas that are marginal for wheat production and in areas at high altitude characterized by a short frost-free period. The amino acid content of the Hiproly is compared with a normal barley strain in Table 5.

Triticale

This hybrid is a man-made cereal grain derived from crossing wheat and rye. CIMMYT's team in collaboration with a group of scientists at the University of Manitoba, have worked during the past 7 years to produce

this new cereal crop. Triticale, in addition to its grain yield potential, has a considerable potential from the nutritional standpoint. The earliest developed triticales showed high content of protein that ranged from 11.7 to 22.5% with an average of 17.5%. Lysine, which is the most limiting amino acid in most cereal proteins, varied from 2.5 to 3.7% with an average of 3.2%. However, these triticale lines usually had severely shriveled kernels, suffered from infertility, and lodged badly. These factors prevented its acceptance as a new cereal grain. Triticales developed during the last 3 years have been improved greatly. At the present time, there are lines with complete fertility and shorter stature and grain yield has risen rapidly (Zillinsky and Lopez 1973). In addition, these lines have been submitted to intensive selection pressures for plumper kernels and higher grain yield. With the improvement of kernel type the grain protein content has decreased but the lysine content in the protein has increased, providing an overall improvement in the nutritional quality of triticale protein (Table 6).

The negative correlation between crude protein and lysine in the protein due to variety and environment, is general in most cereals. The negative correlation is due to a greater relative synthesis of storage proteins low in lysine and other essential amino acids at the higher levels of protein in the seed.

In preliminary feeding trials with animals and in human studies, Kies (1970) showed that the quality of triticale protein is superior to wheat. Up to now, no lines or varieties of wheat have been identified with a significantly

TABLE 5. Content of amino acids in a normal barley strain and a high lysine barley strain.

Amino acids	Barley	
	Normal	High lysine
	g/100 g protein	
Lysine	3.3	4.0
Leucine	6.5	7.9
Isoleucine	3.6	4.0
Methionine	1.2	1.8
Phenylalanine	6.0	6.5
Threonine	3.3	4.0
Valine	4.5	5.6
Protein (N $\times$ 6.25)	14.2	14.8

TABLE 6. Amino acid content in two triticale strains (g/100 g protein).

Lysine	3.6	3.0
Leucine	7.0	10.6
Isoleucine	3.5	3.7
Methionine	1.2	1.3
Phenylalanine	4.9	5.8
Threonine	3.6	3.4
Tryptophan	1.2	1.0
Valine	4.5	4.7
Protein (N $\times$ 6.25)	13.7	16.3

higher level of lysine. Consequently, the major effort to improve the nutritional value of wheat is through the development of varieties with higher levels of protein.

Despite the problems encountered in the development of triticale, it is a promising crop with good potential for use as both human food and animal feed in many areas of the world.

However, breeding programs must develop new varieties with improved agronomic characteristics to produce higher yields and higher nutritional quality as well. To improve the nutritional value of cereal grains the breeders must rely on chemical evaluation of early materials and chemical and biological evaluations in the more advanced materials.

Screening of early materials requires techniques that are simple, rapid, reproducible, inexpensive, and reliable, so they can be employed in the analysis of thousands of samples in a relatively short period of time. In the selected material a more accurate and complete evaluation can be made, since the number of samples has been reduced drastically after the preliminary mass screening.

Chemical methods are used that permit the mass screening for quality in the materials emerging from the breeding programs. It is very important that the geneticists and breeders make proper use of the laboratory reports in selecting the germ plasm for their breeding programs.

CIMMYT Screening Procedure

Protein Total nitrogen determination by the conventional Micro-Kjeldahl technique is used for crude protein estimation. The conversion factor employed is based on the nitrogen of the protein of each cereal grain. We use the factor 5.7 for wheat and triticale; 6.25 is used for maize, barley, and rye.

To accelerate the numerous determinations for protein that are necessary, the Kjeldahl digestion has been speeded up through the use of a test-tube digester rack of 40 tubes on a metal block at $375 \pm 1^\circ\text{C}$. After digestion, the samples can be distilled and the released ammonia titrated.

The digested sample can then be diluted to 75 ml, and in the automated Technicon auto-analyzer the ammonia is determined colorimetrically. The Alkaly-phenol-hypochloric acid reaction is used. 60 samples are recorded on a graph in 1 hr with very good reproducibility between duplicates. Approximately 250 nitrogen determinations can be performed each day with this method.

Lysine The most satisfactory method for determining lysine is by ion-exchange chromatography, using automated amino acid analyzers. However, the apparatus is quite expensive and not suitable for screening the large numbers of materials necessary to evaluate lines in the breeding programs. Therefore, we have adopted the colorimetric method proposed by Tsai et al. (1972) with a few modifications (Villegas and Mertz 1971). The method utilizes 2-chloro-3, 5-dinitropyridine as a reagent for the ϵ -amino group of lysine after enzymatic hydrolysis of the proteins and blocking of the α -amino groups of the free amino acids with copper. After acidification, the excess of 2-Chloro-3, 5-dinitropyridine is extracted with ethylacetate and the absorbance is determined at 390 m - on a Bausch and Lomb Spectronic 20. The results obtained using this method are in good agreement with those obtained using the amino acid analyzer. Up to 180 determinations of lysine can be performed in a working day using the colorimetric method.

Tryptophan The Opienska-Blauth *et al.* colorimetric method modified by Hernández and Bates (1969) has been used at CIMMYT to estimate tryptophan. In maize quality screening, we used tryptophan determination as a single parameter because of the high relationship observed in the endosperm protein between tryptophan and lysine. We use the tryptophan determination only in the mass-screening evaluation of populations and segregating material produced in the maize breeding program. For those materials on which we want exact measurements, we determine the content of lysine following the colorimetric method using 2-chloro-3, 5-dinitropyridine, and never predict the content of lysine simply on the content of tryptophan found.

The colorimetric determination of tryptophan is performed on a papain hydrolysate. The method is based on the formation of a coloured compound resulting from a reaction between tryptophan, acetic acid containing iron ions, and sulfuric acid. The method permits the determination of free and bound tryptophan, and we are able to perform up to 240 determinations per day.

DBC Method

Dye-binding capacity (DBC) has been widely used for rapid mass screening in the evaluation of cereal grains for high protein content as well as for high content of basic amino acids (Mossberg 1969).

The evaluation procedure used in CIMMYT in the evaluation of barley, triticale, and wheat materials is as follows: 500 mg of finely ground sample is shaken with 25 ml of monosulfonic azo dye, acid orange 12 for 1 h. The dye is absorbed by the basic imidazol, guanidine, and amino groups of the proteins. These groups may originate from the basic amino acids histidine, arginine, and lysine as well as from free amino end groups of the protein chains. Since the proportion of basic amino acids in the proteins is reasonably constant, the correlation obtained between DBC and crude protein content is high, so we select the higher DBC values (percent transmission of unbound dye). The high DBC values can be due to high protein or to a high content of basic amino acids in the protein. In those samples showing high DBC we determine the protein content by using the Kjeldahl procedure. Then a variable quantity of sample, depending on the content of protein is weighed in order to have a constant amount of protein (60 mg) in all samples. The dye-binding reaction is repeated, shaking for 1 hr with 25 ml of dye. The percent of light transmission indicates the quality of the protein (level of lysine in the protein). In the selected material the full lysine determination is performed.

Plant breeders, therefore, can develop cultivars having improved quality if there are available techniques for screening segregating materials permitting the efficient selection of

lines with favourable characteristics. However, there still remains a problem in devising biological assays that can be used in mass screening using small animals to evaluate the products for ultimate human consumption. The main drawbacks in the biological approach are that most of them are time consuming, expensive, and require large samples. There is a great need for further research to establish appropriate biological assays that can be used efficiently in the development of cereals with improved nutritional quality.

The efficiency and productivity of agriculture has increased greatly in the developed countries as a result of the coordinated effort of plant breeders, phytopathologists, entomologists, agronomists, physiologists, biochemists, food scientists, etc. In many developing countries, however, we still have low yields, low production, and inferior quality.

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Post-Harvest Protection and Processing of Rice

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Abstract The methods of getting the harvest to the processing plant need to be changed, eliminating middlemen and speeding up delivery to keep pace with increased yields, the characteristics of new varieties, and the wet-season harvest. Problems and strategies are reviewed covering production, drying, storage, milling, and processing plant and management operations. An action plan is recommended, involving the following: engineering research, design, and development to improve existing technologies; field testing for technological efficiency, and redesign for manufacturing with existing country capabilities; operating research to assist planners and policy-makers, and central management; and intensive training for managers, technicians, and extension engineers.

Résumé Il est nécessaire de modifier les méthodes d'amenée des récoltes aux établissements de transformation, d'éliminer les intermédiaires et d'accélérer les livraisons des grains afin de faire face aux augmentations de rendements, aux caractéristiques des nouvelles variétés et aux récoltes en saison humide. L'auteur passe en revue les problèmes et les stratégies relatifs à la production, au séchage, au stockage, à la mouture, aux établissements de transformation et à la régie des entreprises. Il recommande un plan d'action englobant les points suivants: recherches en génie rural, conception et mise au point de techniques meilleures; essais sur le terrain pour vérifier l'efficacité des techniques; redéfinition du matériel afin de permettre sa fabrication suivant les capacités existant dans le pays; recherches opérationnelles permettant d'aider les planificateurs, les décisionnaires et les principaux gestionnaires; formation intensive de cadres, de techniciens et d'ingénieurs vulgarisateurs.

THERE is an over-lapping of concern between the production sector and the processing-marketing sector of the rice industry in the area of harvesting. This is a field operation performed by the farmers. Traditionally the processor's concern starts when the grain is delivered at the processing plant. In the mechanized West, the farmer delivers his harvest to the processing plants, where the crop is weighed, sampled for grade analysis, and the

farmer is paid. In the more languid East, the farmer harvests his crop and waits at the farm or village centre for the middlemen, the procurement agents who work for a commission. The harvested grain is either measured in volume or weighed, and the quality determined as a housewife would determine the quality of fish in the market. During the early part of the harvest season, particularly after a rice shortage crisis, it is a seller's market. The harvest

season quickly peaks and it rapidly becomes a buyer's market, especially during the rainy season. The middlemen arrange delivery of the grain to the processing plant where it is again weighed and graded. This pattern is changing slowly but the change should be accelerated. The traditional methods are inadequate to handle the increased yields, the characteristics of the new varieties, and the wet season harvest.

In the rice-bowls of Asia, harvesting is by manual labour. Mechanical stationary threshers are used in some areas in the Philippines for the dry season crop. No mechanical thresher has gained acceptance by the farmers for the wet-season crop. The agronomists state that physiological maturity of the grain occurs when the grain-kernel moisture content is 26% whereas the engineers claim technical maturity at 21%. Most of the existing commercial equipment (harvesters, threshers, cleaners, combines, and mechanical conveyors) works efficiently when grain moisture is 21% and below. The Japanese and IRRI-developed threshers have yet appeared in Asia. There is an all-weather thresher that is gaining popularity in Cotabato, Southern Philippines. The developer modified the Japanese double-drum thresher, and drives it from the power take-off of his two-wheel tractor. I saw several units being used. It is a throw-in type where the entire crop, straw, stalk and all, is thrown into the machine.

Threshing in the Philippines, Thailand, Malaysia, and Indonesia is done by beating the rice straw against bamboo or wooden slats, against a log, against the sides of a wooden tub, or by beating the rice straw with a stick, or by trampling by people or animals, or by tractors fitted with trailing finned rollers. These methods must be changed because: (1) Harvesting is delayed. This becomes very serious when there is a labour shortage, and this happens in some parts of Asia. The crop becomes over-ripe, shatters, lodges, and is at the mercy of rodents and birds. (2) The crop is cut and laid in windrows or field stacks to await threshing. During the rainy season, the grain moisture is from 26 to 30% (wet basis). The grain ferments, heats up, and with the

high-yielding varieties starts to germinate. The milled rice from this is dark, severely heat-stained, and with a very high percentage of "brokens." High percentage of brokens is correlated with low total milling recovering, and during a rice shortage this milled rice can pass off as red rice. In some areas of the Philippines the people have known only this type, and prefer it to white-polished rice. The most serious danger is the molding. The US Dept. of Agriculture has found aflatoxin contamination in molded padi. I understand the harmful effects of this mycotoxin are not immediate (e.g. cigarette smoking). The toxin is not easily destroyed. A cow that eats molded silage would still have the toxic agent in its milk. The Food and Drug Administration of the Philippines has found it in our rice in the market. It normally takes 3-4 days (sometimes even a week in areas without feeder roads) to bring the wet crop to the processing plant. (3) The crop that is cut during the summer is usually left to sun-dry in the field. The partly dried grain when exposed to sudden April showers is remoistened. Grain that has reabsorbed moisture develops fissures. Unless this is parboiled, it results in poor milling recovery.

We normally recommend that the grain at the right stage of physiological maturity has to be harvested, threshed, and brought to a drying floor or plant within 24 h. Our present methods and facilities cannot comply with this recommendation.

An observation has been made that artificially dried padi compared to sun-drying results is darker-coloured milled rice. We know that it is not the artificial drying by itself that causes the discolouration. We suspect that it is in the delay between harvest and drying. Artificial drying is done only during the rainy season when sun-drying is not feasible. During the summer, the grain moisture of the crop is normally below 21%, and it starts drying the moment the crop is cut and laid in windrows.

Harvesting in Indonesia

A completely different way of harvesting and handling prevails in Indonesia for 40%

of their production (which represents old varieties). The new high-yielding varieties are handled in the more orthodox manner. The old varieties are harvested by cutting just below the panicle and tied into bundles which are sundried in the fields or village squares, and stored in the open. The grain stack is built like a bloated pyramid, with the surface exposed to the elements. The inside remains dry. The whole method eliminates the need for jute bags and storage sheds. Unfortunately the new high-yielding varieties were not bred for this method of handling. As the new high-yielding varieties become more acceptable, and an alternative method of handling and storing becomes available, they plan to reduce this 40%.

In Indonesia, despite the increased production yield per hectare and double cropping, the continued shortages of rice has aroused interest in upgrading the technology of rice processing and distribution.

The interest is to minimize the physical and economic losses. In many countries rice is a political commodity, and therefore of importance to the internal security of governments. The development of the processing sector is spearheaded by governments in most countries of Asia. In the past, many planners, policy makers, and their consultants were unanimous in their opinion that modernization was simply a matter of transplanting a highly developed western technology. The implementation of this has not achieved any measure of success in the Philippines and Indonesia. We have ample evidence throughout the countryside to support this failure. In the Philippines the government has four grain elevators. The private sector has two high-capacity, high-investment, integrated plants. Despite the centralized control and closed-circuit television to monitor operations from the executive lounge, these plants have not been operating for the last 2 years. A third one is struggling to survive. These capital-intensive plants, with their high overhead costs, were depending on potential increased efficiencies (this means higher milling recoveries, better quality milled rice, lower operating costs, year-round operation, and a larger volume of throughput). The financial

feasibility studies with projections based on 68% recoveries indicated something like 30–35% return on investment. For the past two harvest seasons, the plant average milling recovery of one plant was below 60%. That is only a symptom of the many interlocking problems.

In the Asian developing countries I recognize three very basic constraints that have stifled development: (1) The lack of enough local technocrats with the technical education or experience in the planning, design, installation, management and operation of rice processing facilities; (2) The consultative services provided by some agencies have proved to be grossly incompetent in rice process engineering, or at the least, unimaginative. There has been a bull-headed insistence in many cases on a western type and scale of operations; and (3) Bilateral financial loan agreements between developed and developing countries for grain processing facilities are shackled by vested interests in pawning off equipment, regardless of its suitability.

Problems and Strategies

In the four Asian countries of Malaysia, the Philippines, Thailand, and Indonesia, many of the technological problems are common, but the strategies to develop the industry and achieve price stabilization differ. This report is based on personal observations after relatively brief visits to the four countries.

The Philippines

The private sector of the rice industry in the Philippines will continue to handle the processing and marketing of padi and rice. The role of government is regulatory and to provide a favourable climate for investment. The structure of the industry is as it is developing now: production is moving toward a consolidated management of the many small farms through farmer associations or cooperatives; processing and marketing by corporations using modern, capital-intensive facilities. The family-run rice mills will continue to exist. Their small capacities make them more manageable and, with low overhead, expenses are

more resilient to any crisis in the industry. They will, however, have to streamline their operations to remain competitive. The large corporations which have access to credit and the expertise at managing financial resources are establishing linkages with the production sector. These linkages are in the form of production inputs and technical advice. These arrangements between the corporations and farmer groups for a lasting partnership have to be mutually beneficial. The physics of the different steps in the processes may be understood but the engineering of it as part of a total, economic, agri-business operation under the local governmental, social, and technical constraints still requires a lot of intensive study. There have been no success stories so far to contradict this need for research. The private sector therefore has been very timid to seek world bank financing.

Thailand

The rice industry of export-oriented Thailand is well established. They have not gone all out for the new high-yielding strains whose grain quality does meet their standards. Intensification of production is planned on existing rice land through research on acceptable varieties and on the use of other inputs. There may not be a pressing need for change, but the actual physical loss in the harvesting and threshing, in the infested bulk storage godowns, and in the many village mills is unknown but probably very considerable.

Malaysia

Malaysia has opted for government-owned and operated grain drying, storage, and milling complexes using sophisticated technology with a high-volume capacity. To keep these complexes in operation, production and harvesting patterns as well as procurement and distribution of the rice as a commodity will have to conform to plant requirements. They are working toward this under government direction. Under this scheme the interest of the farmers, for political reasons, will continue to be protected. The private sector will still have a fair share of the market, but will have to

compete with these modern government complexes by becoming more efficient.

Indonesia

Indonesia, in its rice program, has chosen to reinforce the farmer cooperatives (the BUUDS) by including processing within their area of activity. The Bureau of Logistics (BULOG) is committed to purchase milled rice from the BUUDS for the national buffer stock. Small-scale drying, milling facilities, and corrugated sheet metal silos are being introduced to the cooperatives. This is an imaginative scheme to increase the farmer's income. If this program succeeds, very few independent millers will survive — where will they get their padi?

The Problems

Production as it affects processing

There are still too many varieties planted, and there does not seem to be any relief from this situation in the immediate future. In a large-capacity, modern processing operation, there is a severe limitation on the number of different grades of padi that can be handled. Alternatives that should be studied include: (a) Programming of production in areas serving a processing plant; (b) Mixing of different varieties having the same physical dimension and biochemical properties; (c) Designing of the processing plant to enable it to accommodate several padi grades simultaneously; and (d) Programming plant operations to handle different padi grades in coordination with harvesting.

The fragmented land ownership results in several thousand farmers dealing with a large-capacity processing plant. An acceptable relationship between the farmers and the processing plant must be established. What is an acceptable arrangement? In the hard harsh business world, the beautiful social concepts to protect the poor small farmer are hard to implement. In the relationship between the sugar central and the planters association in the Philippines there is a parallel, and a con-

tinuous haggling over what is an equitable business agreement.

Harvesting and Threshing

Methods of harvesting, threshing, and hauling of the crop from the field to the plants are still primitive. There is an urgency to mechanize these operations to reduce field losses, particularly when there is a labour shortage and harvesting is delayed. During the dry-season crop there is the danger of moisture reabsorption in the grain which causes fissuring. During the rainy-season crop when the grain moisture is high (26–30%), there is very limited time to bring in the crop before fermentation, molding, or germination occurs. As yet there is no commercial harvester or stationary thresher that is technologically and economically workable that has gained farmer acceptance for the wet-season crop. Either a radically new machine must be developed or an entirely new method of handling the mature crop devised. For example, can we not pre-dry the grain on batch driers right on the farm with grain still on the panicle — like stalk grain? The wet grain chokes the thresher, cannot be cleaned in the plant pre-cleaners, and will not flow in the ducts because of bridging.

Drying

How is drying capability to be provided, especially for the wet-season crop? Is a new drying technology needed, or is the solution to the drying problem one of harnessing an existing technology? In a system where a central drying plant is to be used, what are the economic and management implications of a battery of smaller drying units to provide flexibility to handle different grades as compared to a large single unit? Is the simplicity of operation of batch driers compared to continuous-flow, multistage drying of the same drying capacity an advantage or not?

Central drying plants have a high fixed cost. The cost:benefit ratio is high if they are used only 3–4 months a year. In a well-organized raw material procurement scheme and plant

operation, is it really still cheaper to sun-dry the summer crop which is labour-intensive while a high-cost drying facility is lying idle? Proper handling and drying undoubtedly result in better quality grain and therefore potentially higher milling recoveries. Isn't this enough economic incentive to use grain-drying facilities for the two crops?

To improve the cost:benefit ratio of a drying plant, one possibility is to increase the drying capacity of an existing plant. Because of the high ambient temperature and humidity in the tropics and the fact that padi is temperature-sensitive, other thermodynamic possibilities should be explored.

Farm drying to complement plant drying is an interesting possibility as a way of arresting the rapid biodeterioration. This would also allow the use of smaller plant driers. There are still many engineering problems with the farm dryer design. The power/blower compatibility has to be improved. Theoretically the air volume at the pressures needed requires only about 1 hp, yet because of inefficiencies a 5-hp engine has to be used. Frequently because of poor blower performance the moisture gradient between top and bottom is too high, necessitating manual mixing of the batch. Batch drying as a continuous process is a decreasing rate function dependent on moisture diffusion, and results in 8–10 h of drying time per batch. Can drying be accelerated without complicating the design and operation too much? There may be some mechanical and thermodynamic solutions to the problem.

The oil crisis demands new sources of thermal energy for drying. Old rice milling complexes use rice hulls to generate steam for their steam engines. The same steam could be used for heating the drying air. Combustion furnaces for rice hulls for direct heating could also be developed. Some progress has been made but the systems still crude and difficult to control. A well-designed system may not necessarily add to air pollution.

Many North Americans who are used to drying wheat or corn slowly in deep-bed metal silos during the cool, dry temperate climate in the fall still contend that the same method and equipment can be used in the hot, humid

tropical climate for rice. The drying properties of rice plus thermodynamic calculations indicate there must be a change in method and specifications of equipment to make it work. The large capacity and the possibility of combining farm drying and storage makes it an interesting possibility for Asia. This will require old-fashioned engineering research and development work.

One of the problems of drier utilization is the incompatibility of capacity with requirements. Many driers installed have an overcapacity with respect to the small batches of padi of a certain grade that is received at the drying plant, and have an undercapacity to dry the total volume of grain received within a given period. Studies should be made to give the sliding scale capacity, and to determine optimum capacity for the average run of milling complexes. Or is it easier to change the overall productivity and handling pattern?

Certain auxiliary drying equipment should be redesigned to make it more efficient to handle the extremely wet grain and the high dockage common to the Asian farms. The pre-cleaners, elevators, conveyors, ducts, and unloaders were designed using dry grain data. One other difficulty in the adaptation of equipment designed for other grains for padi is the abrasive nature of padi: drag chain conveyors, ducts, screw augers — the metal that comes in contact with padi wears out very rapidly. This engineering problem has to be solved, because grain is handled as a semi-fluid material, and it must rub against certain parts of the equipment.

Parboiling padi results in an apparent improvement in the grain quality of some inherently poor quality-chalky grains, and an improvement in the milling characteristics. Parboiling on a continuous-flow process before drying should be developed without the objectionable features of primitive parboiling methods. This can alleviate some of the problems of poor grain quality as a result of delayed drying.

There is a consumer preference for aged rice over freshly harvested milled rice. A heat treatment process could be part of the pre-drying process.

The most serious problem of drier utilization in Asia is the lack of trained or experienced plant managers, processing plant engineers, and technicians, and process engineering in extension work. Obviously the instant manpower has to be provided through intensive short-term training courses. The long-term program should include the introduction and strengthening of engineering education. A manpower shortage in grain-process technology is the main problem in the efficient use of the modern facilities in the Philippines, Malaysia, and Indonesia.

Storage

Grain shortages have resulted in rapid turnover of stocks, so experience in long-term bulk storage in tropical climates is very limited. Bulk-stored grain in both Malaysia and the Philippines suffered spoilage in 3 months. Possible reasons include mismanagement of the grain or the system, or inherent engineering deficiencies in design. Was spoilage due to moisture migration, or capillary seepage of water? Are convection currents induced by the limited difference in day and night temperatures? Does thermal conductivity or capacitance of the silo walls affect convection currents? If convection currents are responsible for moisture migration, can they be neutralized by aeration? Forced convection using aeration blowers requires a lot of expensive power. What are the minimum air-volumes required, and how long and how frequently do they have to be applied? During the monsoon season, when humidity is high, what are the limitations in aeration using ambient air? Or is it necessary to condition the air? In many of the bulk storage systems I visited there were no provisions for turning the grain from one silo to another. This is a well-established practice in storage plant management, which may no longer be necessary or accidentally omitted by the consultants. Some concrete silos were not provided with an aeration system. In those with an aeration system, performance is very poor. These variances in design and practice indicate lack of necessary information.

Grain pest infestation is prevalent throughout Asia, in the bulk godowns, gunny bag warehouses, bulk storage bins, "Lumbongs," and most especially in the rice mills. All require different methods of treatment (e.g. spraying, fogging, or fumigation). Insecticide companies prescribe the method for their product but there does not seem to be a follow-up on results.

Rice-deficient countries are stocking up on brown-rice and milled rice. Brown-rice because you take in more rice per unit volume, and milled rice because this is what is sold. Brown-rice becomes rancid rapidly. Milled rice is much more susceptible to weevil infestation. Can we afford low-temperature storage? Aside from general principles as being sure the moisture content is uniformly at storage requirements and regular prophylactic practices, there is lack of specifics on how to do it and its effectiveness.

Thirty to sixty percent of production is retained in the village for local consumption. Low-cost farm bulk storage units (if possible not requiring aeration) must be developed. A better alternative to stalk-grain storage that has the same facility for handling and transport must be developed if we are to convince the Asian farmer such advances are in the national interest.

There has been some pressure to convert flat gunny bag warehouses into bulk storage godowns. This recommendation eliminates the substantial cost of jute bags. An average-size warehouse, 4000-ton capacity (120,000 50-kg bag) at US\$0.60/bag in two seasons represents an addition annual investment of US\$144,000. But converting a low building into bulk storage is not as convenient without extensive machinery. Bulk storage is altogether a different level of technology. This recommendation has to be studied carefully; 4000 tons of spoiled grain is worth \$1,200,000 at pre-inflation rates.

Rice Milling

The art and practice of milling rice with the machines still in use today graduated from the mortar and pestle at the turn of the century

in some of the Asian countries. Some millers, not necessarily of the old school, still swear by the traditional mills. They claim that properly installed and operated, and using clean, good-quality padi, the mills can turn out milled rice that will pass the premium grade of any country. The Thai 100% rice that is coveted by the discriminating is milled in traditional rice mills. New varieties increased milling capability requirements, new scales of unit milling capacity requirements, and economic domination by the industrialized countries have imposed on many of the Asian countries an entirely new milling technology. Capital is needed to expand milling capability, and this is easiest to obtain on a long-term soft-loan arrangement from a country manufacturing rice mills. The Japanese industry has been very aggressive in selling their rubber-roll rice mills. Unfortunately, the Japanese mills were designed for the *Japonica* varieties that are short and round. Their mills have not worked as well for the more popular medium- and long-grain Asian varieties. An attempt has been made to combine the traditional and the new technology of milling. Many people have felt that the new mill using rubber-roll huskers, specific gravity separators, horizontal whiteners, etc. is "the best" rice mill in the world. The World Bank will only finance new mills using the new technology. The Asian Development Bank has a firm opinion on this, but the millers, and some governments, do not think so. Again, this is not a political argument and further research should settle the matter.

Undoubtedly there are some good features of the new milling technology. Many millers have upgraded their traditional mills by adopting the rubber roll in place of the stone disk huskers. This is a continuous-flow process and there are problems of capacity incompatibility. The millers would also like to see a rubber or synthetic that can cut down on replacement cost.

There are some who feel that outright replacement of the stone disk huller is not the best arrangement. They recommend the use of rubber-roll huskers as a return huller for padi from the separator. The theory is that the disk

huller clearance should be adjusted for the normal-size grain. The smaller grain will go through unhulled. If the disk clearance is decreased to take care of the small grain, the percent broken grains increases. Therefore, a separate return huller should be used, and this is better done by a rubber-roll husker. The logic is sound and should be investigated.

Certain millers believe in a different system. The good features of the traditional stone disk huskers can be retained by using a padi grader that will size the grain before husking, using parallel husker for different size grains. If the normal size were 80% of the volume, then the other 20% can be hulled on smaller clearance stone-disk husker, or a rubber roller. The logic is also sound, except the opponents of the system say the padi grader will not last because of abrasion. Further research should settle the issue.

It is claimed that from 30 to 50% of production in Asian countries consumed in the villages is milled in the one-pass iron hullers. This is an adaptation of a coffee grinder that grinds the padi just as well. Percent head grain recovery is low, about 35%, and total milling yields about 60%. The milling potential of most Hrv's is about 68%, and most of the traditional commercial mills average about 65%. If Indonesia now processes 21,070,000 tons of padi with a loss of 5% in milling, recovery of 50% of this loss is equivalent to 526,000 tons of milled rice. There are now attempts at using the small rubber-roll huskers with a one-pass whitener, without benefit of a separator. The milling results are better, but still below par. Very serious work must be done at developing a better mill for use in villages. In some countries like Indonesia that are pushing for integration of milling with production by farmer cooperatives, there is an urgent need for small-capacity milling research and development work.

There are many other components of the milling system that can benefit from engineering: for example, broken rice scavengers at all points in the system, refiners or polishers to improve the gloss, sifters, graders, blenders, and packaging units. In the advanced establishments, automation should be developed and

introduced for automatic control of degree of polish, rather than depending on subjective judgment.

Processing Plant and Management Operation

Some of the problems in management and operation of a processing plant as a business enterprise cannot be itemized as discrete technological problems. A systems analysis is needed to determine pressure points in terms of the ultimate objective of delivering the milled rice to the consumer at maximum efficiency and at a reasonable profit. These are listed below, although some are repeats of the technical problems mentioned earlier: 1 How to manage the many small batches of different grades of padi; 2 How to keep fresh wet padi in its fresh state while awaiting processing; 3 How to decrease maintenance costs due to abrasion; 4 Increasing efficiency of the drying plant; 5 How to clean and convey wet padi; 6 The establishment of a sound business relationship with the suppliers of the raw material (padi); 7 How to improve the procurement scheme that now requires immediate cash payment: the large amounts of cash involved present a security problem; 8 How to institute a workable system of grades and standards to define the quality of padi and rice as a basis for trading: the measures and prices must reflect dockage, moisture content, and milling potential; 9 How to institute a system of inventory control: the simple weighing of wet padi incoming and milled rice outgoing is not enough. With dockage, rice hull, and other by-products discarded at the plant, and these vary greatly, allegations of stock manipulation and even pilferage have been commonplace. The sampling procedures, the laboratory equipment, and inflow weights have to be developed and adopted, as well as an easy record and information system that does not require computers; 10 How to fully understand the technologies involved in heated air drying, bulk storage, milling efficiencies, and quality control measures and their relation to economic performance: the conclusion that heated-air drying is more expensive than sun-drying, for example, convinces central man-

agement to decide that in summer contractual labour must be hired to sun-dry; 11 How to induce the local manufacturing industry to service the processing sector: continued importation is an expensive and frustrating experience; 12 Integration of operations to utilize by-products; and 13 The lack of senior management and technical personnel trained or experienced in modern rice processing plant techniques.

Action Plan

There appear to be four kinds of problems of the rice protection processing and utilization industry. One involves *engineering research, design, and development* to improve existing technologies or to develop new ones. The second category is *field testing for technological efficiency, and redesign for manufacturing with existing country capabilities*. The third requires *operating research* involving utilization of the new technology to assist government planners and policy-makers and central management to be able to make sound decisions. The fourth is *intensive training* for development managers, technicians, and extension engineers.

Problem category one is an expensive item. It requires imaginative design engineers, and a support staff of junior engineers, draftsmen, and machine shop technicians. It requires machine shop facilities, and sophisticated instrumentation. It also requires a well-organized administrative support services. This, therefore, requires a regional rice processing research and development centre, such as IRRI for rice breeding.

Problem category two should be a country program but with financial and technical assistance from the regional centre and existing governmental agencies such as the Philippines' National Grain Authority in cooperation with the University of the Philippines at Los Baños, Thailand's Engineering Department of the Rice Ministry, Malaysia's Padi and Rice Marketing Board in cooperation with the Malaysian Agricultural Research and Development Institute and the Malaysian Agricultural Development Authority, and Indo-

nesia's Bureau of Logistics in cooperation with their ministries of Agriculture and Industry. New equipment or new operational techniques could be tried out on a commercial scale in any of the processing centres of these agencies. Local engineers should apprentice at the regional research centre so they will develop a psychological identity with the work they have to do with the centre in their countries. The country program will also involve selection and adaptation of appropriate available technology.

Problem category three, operations research, requires top grade systems engineers and economists. The pool of design engineers, who are the technical experts in the different unit process operations, can support these analysts. The work involved here is not only analysis of existing plants where the new technologies are being tested, but it can also serve as an international consultancy to governments and private industry in making economic feasibility studies in the design and layout of new plants, in the rehabilitation or upgrading of existing plants, or in the formulation of national rice programs where technical and economic information may be needed.

Problem category four is the most urgent. The trained manpower is needed now to rehabilitate old facilities, to manage and operate new existing complexes, and to serve as extension engineers. The management and principles courses should be organized as regional training programs, but training for utilization should be country programs. The UNDP/FAO have invested in some training facilities at the University of the Philippines at Los Baños. These country programs will terminate at the end of 1974. Negotiations could be made for the Regional Research and Development Centre to take over these facilities to serve as a regional training base. The existing facilities will have to be supplemented with appropriate equipment. The organization and management of the regional training program will have to be under a professionally trained training officer with an engineering background. He will have to organize the course

and recruit resource lectures that are not yet at the research and development centre. It will also be the responsibility of the training officer to assemble information and the preparation of training manuals. Assistance to country training programs from the centre could include the organization of the training course, recruiting resource lectures, and providing training literature. Country training programs should be done as much as possible with existing facilities that the technicians will operate. The administration of recruiting and organiz-

ing the work programs of local engineers to apprentice at the centre or to visit other establishments to increase their research capabilities should also come under the training officer.

Lastly, the many problems of the rice processing industry and its potential economic value, as well as the several hundred millions of Asians that stand to benefit from the solution of many of the problems mentioned, and the internal securities of government, makes early action imperative.



Increasing the Potential of Cassava Through Improved Processing Techniques and Nutritional Enrichment

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Abstract Cassava has been described as a "tropical staff of life" because it is a major source of nourishment in large areas of the tropical zones of the world.

In terms of land productivity and labour input, cassava is the most efficient calorie producer of all the staples. Because of its hardiness and productive capacity, it tends to be relegated to less favourable soils and to the lowest rung of the subsistence cropping system ladder. Its potential as a food source increases whenever and wherever the spectrum of cultivable crops is limited; it enhances the cropping capability and hence the population capacity of the land better than any other crop.

Cassava is basically an energy food. It therefore fulfills a primary role in the diet. In poverty-stricken or remote areas, where people have no access to more nutritious foods, cassava means the difference between subsistence and starvation; under such circumstances it tends to be consumed in excess. Malnutrition is prevalent and cassava has been called a poor food, when in fact, it is the overall food shortage that is the real cause of the malnutrition.

In areas where cassava has become a staple, efficient local methods of processing have been developed; they convert this potentially poisonous plant into a variety of foods that are palatable, nutritious, and easily stored. These methods should be more widely known and improved to enable many regions to achieve a more stable food supply. The nutritional quality could be upgraded at relatively moderate capital cost using modern enrichment techniques.

Because of the superlative production capacity of cassava, it should be a much more important source of food throughout the developing world. As a food source or as an industrial crop to generate higher farm incomes, cassava offers great potential for development.

Résumé On appelle souvent le manioc une "source de vie" pour les tropiques du fait qu'il constitue une base essentielle de l'alimentation dans des zones étendues des régions tropicales du monde.

Sur les plans de la productivité du sol et de l'apport de main-d'oeuvre, le manioc est sans contredit le producteur de calories le plus efficace de tous les aliments de base. Du fait de sa rusticité et de ses capacités de production, on a tendance à le reléguer à des sols

moins favorables et à le situer au dernier rang des cultures vivrières. Ses possibilités en tant que source d'alimentation deviennent plus évidentes dans tous les cas où l'éventail des plantes cultivables est limité. Le manioc, mieux que toute autre culture, rehausse les capacités de production des terres et augmente donc leurs possibilités de peuplement.

Le manioc est essentiellement un aliment énergétique et remplit donc à ce titre un rôle fondamental dans les régimes alimentaires. Dans les régions très pauvres ou éloignées, dont les habitants n'ont pas accès à des aliments plus nutritifs, c'est lui qui fait la différence entre la subsistance et la faim; de ce fait, sa consommation tend à y être excessive. La malnutrition y constitue une dominante et l'on a qualifié le manioc d'aliment de troisième ordre, alors que c'est en réalité la pénurie globale d'aliments qui est responsable de la malnutrition.

On a mis au point des méthodes efficaces de transformation du manioc à l'échelon local dans les régions où il est devenu un aliment de base. Elles permettent de convertir cette plante potentiellement toxique en toute une série d'aliments gustatifs, nourrissants et facilement stockables. Ces méthodes mériteraient d'être mieux connues et améliorées afin de permettre à de nombreuses régions de s'assurer un approvisionnement alimentaire plus stable. Il serait possible, en utilisant les techniques modernes d'enrichissement, d'accroître la valeur nutritive du manioc et ce, avec des investissements relativement modérés.

Du fait de ses capacités de production extraordinaires, le manioc devrait constituer, à travers le monde en voie de développement, une source d'aliments beaucoup plus importante. Sur le plan du progrès de ces pays, le manioc pourrait constituer un atout précieux, que ce soit pour l'alimentation des populations, ou en tant que culture industrielle destinée à accroître les revenus agricoles.

AMONG the important nutrients obtained from nature, the most ubiquitous are the carbohydrates, produced through the process of photosynthesis in the green parts of plants and stored in the form of starch in roots and seeds. Carbohydrate foods, particularly from tuber crops such as yams (*Dioscorea* and *Colocasia* spp.), sweet potatoes (*Ipomoea batatas*) and cassava (*Manihot esculenta*), are the most important sources of nourishment in tropical diets.

Importance in Subsistence Economies

Cassava is one of the most extensively cultivated staple crops in the world. In 1966–70, annual world production was over 88 million metric tons on some 10 million hectares (Table 1). The 1965 level of cassava consumption in the developing regions was estimated at 45 million tons, compared with a total 25 million tons of sweet potatoes and yams. (Table 2).

Information on the utilization of cassava in most developing countries is scanty, but it is apparent that cassava has competed successfully with the traditional staples in many re-

gions; even among some pre-industrial societies in Africa, Southeast Asia, and the Pacific Islands, cassava has usurped the indigenous yams. National statistics frequently mask regional dependence on cassava as a staple; for example, this was tragically highlighted by the Nigerian civil war of 1967–69. In Kerala State in India cassava is now one of the most extensively grown crops. Less than 50 years ago it was noted that "In India and Ceylon, its cultivation is rather limited and generally confined to small gardens" (MacMillan 1925).

The trend toward greater utilization of cassava as a food staple has particularly been noted recently in areas of population pressure or deteriorating environments in Africa where one-third of the carbohydrate intake comes from cassava. By 1970 half of the world total of land planted in cassava was in Africa, although cassava production levels were not comparable. Even in Southeast Asia where rice is deeply entrenched, cassava assumes a role approaching that of a primary staple, especially in times of poor padi harvests or in the overpopulated, hillier, or more arid areas of the Indochinese peninsula and on some of the islands of Indonesia and the Philippines.

FAO has not been able to assemble reliable data on the world production and utilization of cassava products, and has been even less successful with trade statistics. In the subsistence economies of Africa, international trade within a region may be substantial, if not statistically evident. This occurs in East Africa, where cassava was noted in the 19th century as a famine-fighter. Where it has become a staple, whether primary or secondary, the

major cassava-producing countries such as Zaïre, Brazil, Indonesia, and India, export only a fraction of their output, the volume directly affected by the general food supply; hence such countries may not be exploiting the more productive agronomic techniques properly associated with cash cropping.

Where cassava is grown as an insurance against failure of the more sought-after staples due to pest or disease or drought, large areas of planted cassava may remain unharvested. In such instances, the crop is relegated to marginal lands and its potential barely exploited. Thus, even when yields are reported low, cassava may have the undramatized but vital function of a food bank, since the plant can live for up to 4 years. This sometimes means the difference between starvation and subsistence levels in many remote village economies of the tropics (Table 3).

Because tropical diets are too often distinguished by an inordinately heavy, at times exclusive, dependence on the primary staple, the importance of this food crop is probably greater than is suggested by statistical data. In the period 1964–68, nearly 30 countries of the tropical world depended upon cassava as the primary staple; of these, nearly 20 derived over 10% of their total calorie intake from cassava products, from which Gabon and the Central African Republic obtained about half of their energy food (Table 3).

TABLE 1. Cassava area and production 1948–70 (source: FAO Production Yearbook 1971, vol. 25).

	Area ('000 ha)		
	1948–52	1961–65	1966–70
Africa	4,073	4,616	4,840
North and Central America	128	93	95
South America	1,278	1,931	2,356
Asia	1,380	2,268	2,277
Oceania	8	10	11
World	6,867	8,918	9,578
	Production ('000 tons)		
	1948–52	1961–65	1966–70
Africa	25,232	30,693	35,445
North and Central America	562	532	593
South America	15,061	25,224	32,271
Asia	9,657	18,486	19,745
Oceania	66	112	121
World	50,578	75,048	88,175

Major Producers 1970	Production ('000 tons)	Area ('000 ha)
Brazil	29,464	2,025
Indonesia	10,451	1,434
Zaire	10,000	800
Nigeria	7,300	1,100
India	5,216	353
Uganda	2,150	250
Mozambique	2,100	430
Burundi	1,577	184
Tanzania	1,500	285
Madagascar	1,218	185
Central African Rep.	1,000	200
Cameroon	930	190
Malaysia	355	22

TABLE 2. World staples 1971 (source: FAO Production Yearbook 1971, Vol. 25).

	Area (ha)	Production (tons)	Yield (tons/ha)
Wheat	217.2	343.1	1.58
Rice	134.9	307.4	2.28
Maize	112.9	307.8	2.73
Potatoes	22.5	306.4	13.60
Yams and sweet potatoes	17.0	147.7	8.70
Cassava ^a	9.8	92.2	9.40

^a1970 data, excluding Mainland China.

TABLE 3. Average per caput caloric intake, 1964-68 (based on FAO Food Balance Sheets 1964-68). Listed are countries where cassava is the chief starch staple but excludes those where cassava may account for over 10% of the caloric intake yet is not the chief staple (e.g., Uganda). Cassava consumption accounts for over 13% but plantains contribute an even higher proportion of the caloric intake.

	Calories per day		Cassava %	
	All foods	Starchy foods	All foods	Starchy foods
Congo (Leopoldville)	2036	1193	59	87
Congo (Brazzaville)	2160	1450	55	82
Gabon	2182	1536	53	75
Central African Rep.	2172	1177	49	90
Mozambique	2127	929	43	98
Angola	1911	864	35	76
Togo	2222	590	27	69
Liberia	2287	746	26	80
Paraguay	2732	743	20	73
Dahomey	2173	785	20	56
Sudan	2091	445	18	85
Indonesia	1760	338	15	76
Ghana	2084	993	15	31
Nigeria	2166	653	14	47
Cameroon	2228	759	14	41
Guinea	2059	424	13	61
Tanzania	2144	414	12	63
Madagascar	2387	386	11	69
Brazil	2541	410	11	67

Technology and Toxicity

The importance of cassava in the subsistence patterns of tropical economies is remarkable because the species widely used for food contain hydrocyanic acid (HCN). A few sweet varieties concentrate HCN in the skin and can be eaten like a fruit after peeling. The toxic nature of cassava renders it pest-free, and its high drought tolerance has enabled the crop to spread even to environments where other food crops are preferred but that are not as productive as cassava.

The conversion of a poisonous plant into a range of palatable foods involves a long, complex process, and cassava was already an "industrialized" crop in pre-Columbian equatorial America: the grater and basket press, the principles of which underlie modern tuber-starch extraction processes, were outstanding pre-industrial Mayan technological aids. Par-

ticularly important was an edible flour, "farinha de mandioca," that sustained many Amerindian tribes in the forested hinterlands of South America for countless centuries; this food is similar to the Nigerian "gari," the Indonesian "gaplek," and the "lemang ubi" of the Malayan aborigines. It is a more nutritious and palatable food than the pure starch "sago," "tapioca," or "Brazilian arrowroot" of international commerce. "Pan de sal" (Filipino wheat-bread), "landang" (Indonesia cassava rice), "tape" (Indonesian fermented cake), and cassava "chapatis" (Indian bread) are some of the foods developed outside the indigenous home of the crop, which serve as a rice substitute or to reduce dependence on wheat-based foods.

In the countries of adoption, the village technology developed for plantains and indigenous tuber crops, even for cereals, has

been modified to process the crop to suit local food needs and preferences; e.g., in Southeast Asia, grating and sieving equipment used by villagers is made from bamboo, which also provides receptacles to cook or bake the tubers. Soaking, pounding, grinding, fermenting, boiling, and roasting of the tubers, and flour baking, enable a variety of foods to be produced that can be stored for long periods and can be depended upon to sustain the population through periods when other sources of food, such as meat, are scarce. Cassava leaves (with up to 10% protein) and fermented beverages augment the nutritional quality of the diet.

Dietary Value

In the course of its acceptance as a West African staple, cassava has been maligned as a poor food. However, cassava is rich in Vitamin C and calcium, but like most tuberous staples, it is deficient in protein and fat (Table 4). It is therefore inadequate as a source of the nutritive components, and protein deficiency is quite marked if a cassava-staple diet is not supplemented with animal protein. But then, all the major staples are deficient in many of the elements required in a balanced diet; even diets rich in vegetable protein have been observed to cause ill health. Because of

TABLE 4. Food composition of staples (1000 g) (sources: First International Symposium on Tropical Root Crops 1967; Holleman and Aten 1956; Jones 1959).

	Water (g)	Riboflavin (mg)	Niacin (mg)	Thiamine (mg)	Vitamin C (mg)	Vitamin (I.U.)	Iron (mg)	Calcium (mg)	Fat (g)	Protein (g)	Carbohydrate (g)	Food energy (cal)
Irish potatoes	780	0.3	14	1	100	— ^a	7	80	1	20	189	820
Sweet potatoes	700	0.5	6	1	230	5000	1	340	4	13	273	1170
Cassava	625	0.3	6	0.6	360	— ^a	7	330	3	12	347	1460 ^d
Yams	724	0.3	5	0.9	100	— ^a	8	220	2	24	241	1050
Taro	725	0.3	9	1.5	50	— ^a	11	230	2	19	232	1040
Maize												
Whole meal	120	1.1	20	4.5	na	4500 ^b	23	210 ^c	43	95	729	na
Fine meal		0.8	46	1.8	na	3006	12	50	12.1	84	773	na
Wheat												
Whole meal	120	1.0	46	4.1	na	0	40	360	23	122	718	na
White flour		0.4	11	1.3	na	0	10	160	11	109	755	na
Rice												
Husked	130	4.5	46	3.3	na	0	14	150	18	75	767	na
Milled		0.3	16	0.8	na	0	9	100	7	67	787	na
Adult male nutritional need per day		1.2	15	1.2	25	2500	8	500		65		2500

^aTrace.

^bWhite maize has little calcium.

^cValue is much less for maize from America.

^dFarinha 3000 cal.

its hardiness and productivity, cassava provides the cheapest and most readily available source of food to large numbers of rural people who cannot afford, or have little access to, more nutritious and more expensive food, and under such circumstances tends to be consumed to excess. More than any other commonly available food, cassava fulfills the first requisite of any diet, i.e., as a bulk food and source of energy. Malnutrition, therefore, cannot be caused by any particular food but by a defective food supply.

Cassava is reputed to be the highest calorie yielder per unit area and to require the lowest husbandry input per calorie (Tables 5 and 6). There is considerable variation in the productivity of the crop in various countries; e.g., Gabon, Zambia, and the Ivory Coast achieve yields averaging 3 metric tons per hectare, whereas in Southeast Asia, West Africa, and India, yields of 10–15 tons are prevalent. With 16 tons, which is twice the world average,

Malaysia is the most efficient cassava producer.

Indications are that there is tremendous scope for the genetic improvement of this crop. Little is known about the genus to which cassava belongs, a handicap further aggravated by the loss or depletion of many collections, notably in Brazil, Tanzania, Malaysia, and Indonesia. Recent genetic work, particularly in Kerala, India, gives hope that cassava clones of suitable growth capacity to suit different ecological situations and for different uses can be obtained. At present, like most tuber crops, cassava is very much the Cinderella in the agricultural research programs of the developing world. The history of research into the genetic and ecological aspects of the plant is dismal, and in no way matches developments already made for temperate cereals, tuber crops, and tropical cash crops.

Because of its low protein content (under 1%), attempts have been made to breed high-protein clones with other *Manihot* species, but these have not been successful; this is also a protracted procedure that offers no immediate solution for countries with urgent food problems. In view of the behaviour of crop yields under different agronomic and climatic conditions, this line of research is less economic or certain than the more direct, more rapid methods being developed at the processing end. One might question further if this is not a misguided policy at this stage, when the greatest attribute of the crop, i.e., as a supplier of calories rather than proteins, should be exploited more fully.

TABLE 5. Comparative yields of staples in Africa (source: First International Symposium on Tropical Root Crops 1967).

Crop	Crop (tons/ha)	Wheat equivalent (tons/ha)
Cassava	14.28	3.29
Sweet potato	6.08	1.82
Maize	1.79	1.34
Eleusine millet	0.95	0.65
Rice (rough)	0.80	0.65

TABLE 6. Comparative labour requirements of tropical staples (source: First International Symposium on Tropical Root Crops 1967).

	Cultivation (man-days/acre)	Harvest and storage (man-days/acre)	Yield/acre	Yield/man-day
Cassava	88	38	12,650	109
Yams	105	39	8,750	67
Sweet potato	51	21	5,430	75
Maize	37	19	1,600	27
Large millet	20	11	852	27

The trend now in nutritional improvements is toward enrichment either by fermentation or additives, and several such processes have been developed in the industrialized countries in anticipation of the food demands of the developing world. These products also offer alternative sources of livestock feeds, which at present in the developing countries are either imported at great expense from the industrialized countries or are formulated on the basis of imported raw materials.

Commercial Value

Tropical tuber crops have not generally achieved a high degree of importance in modern international commerce. Nevertheless, with arrowroot (*Maranta arundinacea*) and the sweet potato, cassava is outstanding as a source of starch; in the last 15 years, cassava products have also emerged as desirable raw materials for compound livestock feeds.

In international commerce, cassava is marketed as dried roots, meal, chips, pellets, flour, starch, and pregelatinized starch products. Cassava starch and its derivatives face competition from a variety of cereals and tubers, and technological advances show that it is possible to treat one starch to simulate the properties of another. Similarly, cassava competes with maize, soya bean, barley and oilseed and cake as basic feedstuff ingredients. In Germany, Denmark, Austria, and Japan, much of the starch supply is for the food industries, whereas in India and the Netherlands, most is used for industrial purposes.

The starch conversion industries are outstanding and expanding components in the industrialized economies, based on domestic starch commodities, mainly maize, wheat, and potato. Although considerable restrictions are imposed on the use of tropical starch sources for food and industrial purposes and on the more processed forms of cassava from the export sources, via tariff barriers and quotas, it would appear to be no longer economic for several of the industrialized countries to overprotect their high-cost domestic cereals against cheaper substitutes from outside the region.

Rising standards of living in both the industrialized and developing economies are leading to increasing demand for more nutritious and diversified farm products. The manufacture of compound livestock feedstuffs is normally concomitant with the establishment of the livestock industry; the potential for growth is enormous in the developing countries where present per capita meat consumption is low. The inflationary trend of the past year has shown more clearly the need to use more economic sources of raw materials for the livestock feed industries of the industrialized world, and on the opposite scale, this trend also underlines the need for the developing countries to process them for domestic usage, where at present they are dispersing limited capital resources on the more prestigious imported substitutes.

The shift toward the great utilization of cassava by the compound livestock feed industries of the industrialized economies was already apparent in the early 1960s. Thailand immediately responded to the rapidly expanding market and by 1970 some 70% of its cassava production was geared to this market: it is the only country to pelletize its products for export. Despite highly variable quality, the market for these products in Germany is yet to be saturated; the Dutch feedstuff manufacturing industry could use three times as much as its present volume of over 1 million tons annually. The Dutch, Belgian, and German livestock feed industries account for three-quarters of the livestock feed production in the European Community; by 1970 they were estimated to produce over 20 million tons of livestock feeds. The higher quality cassava products from Indonesia and a few African countries are sought-after but supplies are erratic and small.

More discriminate processing to take advantage of the higher prices for better grade products would be highly profitable to producing countries that could set aside substantial regular quantities of the desired quality for export. Although the establishment of a competent marketing organization to regulate the quality and quantity of production on behalf of cassava producers would ensure more

equitable prices being secured for their products, there is also the need for a fundamental change in the traditional trading pattern between the developed and developing worlds, viz. the encouragement of more advanced processing to yield less bulky and higher value products, in order to circumvent the high freight costs that at present leave low profit margins for the raw material producers.

A noteworthy feature of the cassava industry in many producing countries is the proliferation of processing methods particularly suited to smallholder or village production; in a few countries, such as Thailand, Malaysia and Indonesia, they co-exist with the larger capital-intensive commercial enterprises of varying scales of operation. It is therefore not essential to the improvement of cassava production to revolutionize processing methods. More crucial to the objective would be the stabilization of the political and social situation, thus facilitating the induction of the more productive techniques into traditional food processing systems.

With its outstanding qualities, cassava could contribute proportionately more than other food crops toward the food supply, either directly, by providing a greater diversity of and more nutritious foods to the population, or indirectly, by increasing the export wealth that could be deployed for improving nutritional standards or as the dietary basis of the livestock industry.

Cassava Production in West Malaysia

In West Malaysia, the technical expertise of cassava production, developed for more than a century (since cassava was one of the most profitable export crops in the 19th century), is of a high calibre, and it yields a starch that meets international standards. The industry could achieve higher output except for the fact that because of various complex reasons, there is insufficient land for cultivation of this crop. In spite of a greatly expanded processing capacity between 1968 and 1971, cassava production unexpectedly fell from 60,000 tons in 1968 to less than 30% of the 1968 production in 1971.

Pragmatically, the industry has incorporated sparingly a few modern components, notably the centrifuge and the cyclone, into the traditional system of processing; it may be considered a fine example of intermediate technology in operation. Significantly, an integrated modern plant operated by a quasi-government agency has been much less flexible in the face of a similar raw material supply crisis.

Chip processing on the other hand is a village industry, literally a backyard operation, where a chipping wheel, a cement court, and portable roofs are the only essential facilities. Thus it yields an inferior product, which nevertheless is prized by pig farmers; in fact production falls far short of demand. The quality of chip products could be considerably upgraded with low capital inputs at the post-harvest and the processing stages, primarily to ensure a higher standard of hygiene.

Like the rest of Southeast Asia, West Malaysia is a net importer of animal feed materials. Some 70–80%, valued at \$64 million in 1971, of which almost half consisted of poor quality maize from her immediate neighbours, were imported for the production of over a quarter million tons of livestock feed in 1970; by 1980, these imports will rise by \$15 million to cost \$100 million. Cassava is very much under-utilized by the domestic livestock feed manufacturers. Together with the waste products of other forms of agricultural processing, namely sugar and pineapple, cassava could yield an inexpensive, nutritious feed, a development made all the more urgent by the present inflationary prices for imported feeds; in the past year the cost of pig rearing has risen by 50% and more.

The tin mining industry in Malaysia has left large tracts of wasteland, particularly in the Kinta Valley, the largest tin mining area in the world. Over the past two decades, subsistence farmers in this region, without other forms of livelihood, have resorted to utilizing such land for cassava cash cropping. In spite of the poor quality of the land and unsuitable environment of this area, and the lack of irrigation or fertilization, there has been relative success with the cultivation of cassava. It is

worthwhile considering the rehabilitation of wasteland under cassava, with the aid of green manuring with legumes. This crop-rotation-livestock system could be augmented by irrigation from the abundant mining pools, and fertilized suitably, in a manner similar to hydroponic techniques. Like many developing countries, Malaysia cannot afford to continue for too long to deplete its forest reserves for cropping and must rehabilitate its devastated land; cassava has been shown by the subsistence farmers, as elsewhere in the tropics, to be able to utilize such soils productively.

At the University of Malaya (Kuala Lumpur) research into the nutritional enrichment of cassava by fermentation methods is progressing, and the potential of leaf and tuber meal for livestock feeding is being investigated. The Malaysian Agricultural Research and Development Institute (Serdang) has produced cultivars capable of yielding over 40 tons/hectare.

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Processing and Utilization of Cowpea, Chickpea, Pigeon Pea, and Mung Bean

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Abstract This paper reviews the literature on the processing and nutritional value of the grain legumes cowpea, chickpea, pigeon pea, and mung bean. These grains, although widely eaten in certain parts of Africa and Asia, offer tremendous potential to meet the ever-increasing demands for food in the less-developed countries. The development of high-yielding varieties of food grain legumes with improved nutritional value is a major aim of the International Crops Research Institute for the Semi-Arid Tropics. The paper includes recommendations for a comprehensive survey of the traditional cooking methods of grain legumes and the nutritional implications, for the identification of appropriate milling characteristics, improved milling techniques and technology, and for identification of the anti-nutritional and digestibility factors to ensure wider acceptance of the products.

Résumé Ce texte passe en revue une série de publications sur la transformation et sur la valeur nutritive des légumineuses-grain ci-après: dolique, pois chiche, pois cajan et haricot mungo. Bien que déjà consommés sur une grande échelle dans certaines parties d'Afrique et d'Asie, ces légumes secs offrent des possibilités extraordinaires de satisfaire à la demande alimentaire sans cesse croissante des pays les moins développés. La création de variétés de légumineuses-grain alimentaires à rendement élevé, de qualité nutritive meilleure, constitue l'un des buts importants de l'Institut International de Recherches sur les Cultures des Régions Tropicales Semi-Arides. Le texte comporte des recommandations en faveur d'une étude d'ensemble des méthodes traditionnelles de cuisson des légumineuses-grain et des implications qu'elles comportent sur le plan nutritif, en vue d'une détermination des caractéristiques de mouture appropriées, de l'amélioration des techniques et de la technologie meunières et en vue de l'identification des facteurs défavorables sur les plans nutrition et de la digestibilité et ce, afin d'élargir la marge d'acceptation de ces produits.

Introduction

Significant breakthroughs in the processing technology of the oilseed legumes soybean and groundnuts have been achieved in de-

veloped economies. But the potentials for food grain legumes which are widely consumed among the subsistence population of the semi-arid zones of Africa and Asia, particularly in the subcontinent of India, have

TABLE 1. Area, production, and yield of legumes, 1948-52, 1961-65, 1967-71.^a

	Area, '000 ha							Production, '000 metric tons							Yield/hectare, 100 kg						
	1948-52	1961-65	1967	1968	1969	1970	1971	1948-52	1961-65	1967	1968	1969	1970	1971	1948-52	1961-65	1967	1968	1969	1970	1971
<i>Chickpeas</i>																					
Europe	542	399	382	366	296	279	254	231	206	240	217	179	169	162	4.3	5.2	6.3	5.9	6.0	6.1	6.4
N. & C. America	125	134	179	206	203	205	210	92	118	133	163	156	164	170	7.4	8.8	7.4	7.9	7.7	8.0	8.1
S. America	19	19	17	21	20	23	21	12	13	15	12	11	16	13	6.3	6.8	8.8	5.7	5.5	7.0	6.2
Asia	9103	10843	9462	9781	8550	9089	9104	4807	6443	4462	6750	5195	6353	5983	5.3	5.9	4.7	6.9	6.1	7.0	6.6
Africa	411	470	493	548	506	593	561	228	259	275	353	295	371	342	5.5	5.5	5.6	6.4	5.8	6.3	6.1
World Total	10200	11865	10533	10922	9575	10189	10150	5370	7039	5125	7495	5836	7073	6670	5.3	5.9	4.9	6.9	6.1	6.9	6.6
<i>Cow peas</i>																					
Europe	1	8	7	7	7	7	7	1	5	5	5	5	6	6	10.0	6.3	7.1	7.1	7.1	8.6	8.6
N. & C. America	157	47	38	35	33	30	33	68	28	22	21	20	18	20	4.3	6.0	5.8	6.0	6.1	6.0	6.1
Asia	41	54	53	49	50	50	49	33	35	32	32	30	34	32	8.0	6.5	6.0	6.5	6.0	6.8	6.5
Africa	1355	2445	2714	2819	3038	3027	2996	438	964	923	975	1082	1102	1084	3.2	3.9	3.4	3.5	3.6	3.6	3.6
Oceania	2	2	3	6	2	3	3	1	1	1	3	1	1	2	5.0	5.0	3.3	5.0	5.0	3.3	6.7
World Total	1557	2555	2815	2916	3130	3117	3088	540	1033	983	1036	1138	1161	1144	3.5	4.0	3.5	3.6	3.6	3.7	3.7
<i>Dry beans</i>																					
Europe	3319	4149	3701	3464	3227	3154	3250	737	924	942	804	885	857	913	2.2	2.2	2.5	2.3	2.7	2.7	2.8
USSR	134	56	45	35	32	40	40	72	73	77	62	64	62	68	5.4	13.0	17.1	17.7	20.0	16.3	17.0
N. & C. America	1963	2860	2927	2911	2830	3148	3102	1255	1879	1880	1941	2016	2136	2224	6.4	6.6	6.4	6.7	7.1	6.8	7.2
S. America	2136	3330	4123	4099	4103	3959	4274	1465	2204	2893	2694	2482	2534	2800	6.9	6.6	7.0	6.6	6.0	6.4	6.6
Asia	4776	8011	8676	8532	8545	8790	8380	1468	2654	2974	2820	2958	3213	3028	3.1	3.3	3.4	3.3	3.5	3.7	3.6
China P. Rep.	1781	1890	1950	2000	2000	2000	2000	1124	1262	1370	1390	1390	1390	1400	6.3	6.7	7.0	7.0	7.0	7.0	7.0
Africa	1227	1403	1576	1629	1711	1907	1817	656	840	916	964	1213	1335	1249	5.3	6.0	5.8	5.9	7.1	7.0	6.9
Oceania	1	1	2	2	6	4	5	1	1	1	1	4	1	4	10.0	10.0	5.0	5.0	6.7	2.5	8.0
World Total	15337	21712	23000	22672	22452	23002	22868	6778	9826	11053	10676	11012	11531	11686	4.4	4.5	4.8	4.7	4.9	5.0	5.1
<i>Pigeon peas</i>																					
N. & C. America	38	33	32	31	31	30	30	21	20	25	26	25	25	25	5.5	7.9	7.8	8.4	8.1	8.3	8.3
S. America	9	8	12	13	14	14	14	7	4	6	7	7	8	8	7.8	5.0	5.0	5.4	5.0	5.7	5.7
Asia	2249	2544	2603	2737	2599	2746	2723	1322	1685	1149	1766	1847	1871	1871	5.9	6.6	4.4	6.5	7.1	6.8	6.9
Africa	136	128	121	146	156	147	147	53	54	57	59	81	64	71	3.9	4.2	4.7	4.0	5.2	4.4	4.8
World Total	2432	2713	2768	2927	2800	2937	2914	1412	1769	1237	1858	1960	1968	1975	5.8	6.5	4.5	6.3	7.0	6.7	6.8
<i>Dry broad beans</i>																					
Europe	892	844	732	761	750	704	657	766	856	966	947	1029	918	875	8.6	10.1	13.2	12.4	13.7	13.0	13.3
N. & C. America	58	58	61	59	71	72	72	26	41	46	35	36	38	44	4.5	7.1	7.5	5.9	5.1	5.3	6.1
S. America	138	208	269	257	248	239	236	106	125	149	136	136	126	128	7.7	6.0	5.5	5.3	5.3	5.3	5.4
Asia	104	87	83	73	72	68	66	102	97	97	87	90	80	83	9.8	11.1	11.7	11.9	12.5	11.8	12.6
China P. Rep.	2935	3050	3050	3050	3050	3050	3090	2890	2940	3100	3000	3200	3300	3400	9.8	9.6	10.2	9.8	10.5	10.8	11.0
Africa	425	509	501	472	535	541	552	448	552	459	632	638	661	683	10.5	10.8	9.2	13.4	11.9	12.2	12.4
Oceania	1	—	—	—	—	—	—	1	—	—	—	—	—	—	10.0	—	—	—	—	—	—
World Total	4567	4757	4696	4672	4726	4674	4673	4390	4612	4817	4837	5129	5123	5213	9.6	9.7	10.3	10.4	10.9	11.0	11.2
<i>Soybean</i>																					
Europe	46	20	56	54	58	92	164	26	15	50	50	56	104	193	5.7	7.5	8.9	9.3	9.7	11.3	11.8
USSR	383	832	850	854	850	870	880	166	394	543	528	434	603	610	4.3	4.7	6.4	6.2	5.1	6.9	6.9
N. & C. America	5155	12143	16267	16886	16883	17330	17383	7397	19806	26890	30487	31129	31146	32247	14.3	16.3	16.5	18.1	18.4	18.0	18.6
S. America	46	375	691	801	1004	1425	1821	55	406	836	791	1231	1686	2459	12.0	10.8	12.1	9.9	12.3	11.8	13.5
Asia	1386	1630	1600	1663	1542	1693	1556	1017	1190	1191	1215	1187	1331	1225	7.3	7.3	7.4	7.3	7.7	7.9	7.9
China P. Rep.	9774	13238	13460	13350	13650	14300	14300	7282	10626	11100	10670	10920	11430	11500	8.1	8.0	8.2	8.0	8.0	8.0	8.0
Africa	35	46	44	40	66	53	62	17	31	29	20	50	37	45	4.9	6.7	6.6	5.0	7.6	7.0	7.3
Oceania	—	1	1	2	2	4	16	—	1	1	1	1	3	12	—	10.0	10.0	5.0	5.0	7.5	7.5
World Total	16024	28286	32969	33650	34055	35767	36182	15952	32468	40640	43762	45008	46340	48291	10.0	11.5	12.3	13.0	13.2	13.0	13.3

^aSource: Food & Agricultural Organization, Production Yearbook, 1972.

remained virtually untapped. In spite of the increasing demands for more food, the FAO production and yields estimates for the food grain legumes cowpea (*Vigna senensis*), chickpea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), and mung bean (*Phaseolus aureus*) have been at a constant level for 20 years (Table 1).

The unexploited potential of these food legume species has become a matter of concern among governments of developing nations. In concert with international development agencies, these governments have triggered efforts to launch a major research effort into the development of high-yielding varieties of food grain legumes of improved biological value and adaptive food-use properties. In 1972, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established to achieve this objective.

At the same time, the Protein Advisory Group of the United Nations (PAG) has drawn guidelines and recommendations for research to include the total comprehensive system of food legume production processing and utilization (Protein Advisory Group of the United Nations System 1973). The contention is that improved utilization of traditionally prepared foods and the development of appropriate food from legumes are vital to help alleviate the world hunger situation.

Purpose and Scope

Food-use properties for cereal grains, to some extent, have been successfully designed to suit specific usages through genetic manipulation of their chemical and biochemical characteristics. This type of research has been sadly overlooked in food legumes. The purpose of this paper is to (1) identify current practices of processing grain legumes for food in subsistence economies, and (2) identify problems related to traditional processing procedures and forecast prospects for improvement.

I will confine myself to the grain legumes chickpea, cowpea, pigeon pea, and mung bean which are of minor importance to developed nations but nonetheless name the most important source of nourishment of the poor in the semi-arid tropics.

Dietary Contribution Potential

Food grain legumes contain 22–25% protein (Esh and Som 1952; Lal et al. 1963; Singh et al. 1968; Oyenuga 1966), a level which is more than double that in cereal grains. Grain legumes are considered poor sources of dietary protein unless properly heat-processed and eaten with supplements of one or two essential amino acids (Evans and Bandemar 1967; Table 2).

TABLE 2. Chemical composition of chickpea, cowpea, pigeon pea, and mung bean.

Chemical composition	Chickpea			Cowpea			Pigeon pea			Mung bean		
	4.0 ^a	— ^b	— ^c	3.0 ^a	— ^b	— ^c	— ^a	— ^b	— ^c	3.0 ^a	— ^b	— ^c
Ash %												
Protein %												
(N × 6.25)	23.0	—	25.0	25.0	25.0	—	—	24.0	24.0	26.0	29.0	23.0
Ether ext. %	4.0	—	5.0	2.0	3.0	—	—	1.0	2.0	3.0	1.0	1.0
Crude fiber %	5.0	—	—	3.0	2.0	—	—	8.0	—	4.0	5.0	—
N free ext. %	64.0	—	—	67.0	67.0	—	—	62.0	—	65.0	60.0	—
P mg/100 g	366	—	295	459	451	—	—	280	321	313	320	30
Ca mg/100 g	296	—	191	243	90.0	—	—	129	154	199	91	14
Fe mg/100 g	7.0	—	—	7.0	4.0	—	—	5.8	—	8.0	6.0	—

^aSingh et al. (1968).

^bOyenuga (1966).

^cEsh and Som (1952).

The essential amino acid composition of grain legumes has been determined by a number of workers (Block and Weiss 1956; Patwardhan 1962). Venkat Rao et al. (1964), Vijayaraghavan and Srinivasan (1953) and Klimenko and Grigorchik (1970) clearly indicated (Table 3) that chickpea, cowpea, pigeon pea, and mung bean possess sufficient amounts of the essential amino acids except for cystine, methionine, and tryptophan. These findings were substantiated in later studies by Esh (1958), Aykroyd and Daugherty (1964), and Evans and Bandemar (1967).

Since cereal grains are rich in the essential amino acid not found in grain legumes and the latter contain good amounts of lysine which is found in low levels in cereal grains, the grains can complement each other to provide protein of high biological value.

In general, grain legumes with the exception of the oilseeds have very low fat content (1–2%). They contribute minimal amounts of vitamin A, riboflavin, and ascorbic acid. However, their thiamine and nicotinic acid content is fairly high (6–7 mg/100 g). And since they are known to contain phytic acid, which is believed to render Ca and Fe insoluble, their Ca and Fe may not always be available (McCance and Weddouson 1960).

Evans and Bandemar (1967) have shown that most legumes contain toxic factors which can adversely affect the nutritive value of their protein. Borchers and Ackerson (1950) have reported the presence of trypsin inhibitor in

chickpea and mung bean. Liener (1962) strongly suspected the presence of one or more of the anti-nutritional principles (trypsin inhibitor, hemagglutinin, cyanogenetic glucoside, and alkaloids) in chickpea, cowpea, pigeon pea, and mung bean.

Zimmerman et al. (1967) investigated the concentration gradient for protein, lysine, and methionine, and the antitryptic activity in the cotyledon of chickpea. The antitryptic activity was measured as the percentage difference of the optical density between the digestion solution without the inhibitor extracts and the one containing it. The outer cotyledon layer is 30% richer in protein than the inner layer. The factors responsible for antitryptic activity followed a similar pattern. From a nutritional point of view there is sufficient indication that fractionation of the cotyledon if technically feasible may provide protein-rich materials of potentially high value. A differential heat treatment in accordance with the antitryptic activity in the fractions may improve the nutritional value of the protein-poor material and concurrently save further nutrient distraction where antitryptic activity is at low levels.

Definitive information on the presence of the antinutritional principles in nutritionally valuable food legumes is required to help identify food processing procedures that can minimize or completely eliminate anti-metabolic activities before food legumes are eaten.

TABLE 3. Essential amino acid composition of chickpea, cowpea, pigeon pea, and mung bean.

Essential amino acid	Chickpea	Cowpea	Pigeon pea	Mung bean
Arginine	6.9	7.8	5.4	5.7
Histidine	2.3	3.0	3.4	2.7
Isoleucine	6.0	4.8	5.7	5.5
Leucine	8.0	10.4	7.0	7.2
Lysine	6.4	9.6	6.4	6.0
Cystine	0.8	—	0.8	0.7
Methionine	1.7	0.7	0.9	1.1
Phenylalanine	5.0	5.7	9.1	5.4
Threonine	4.8	3.8	3.4	4.3
Tryptophan	0.6	1.4	0.2	0.5
Valine	5.4	5.4	5.1	6.4

Processing of Grain Legumes

It is not uncommon in most parts of South-east Asia, India, Middle East and Africa to find certain legume species consumed as fresh pods, young seeds, and germinated seeds. Immature seeds are popularly parched and eaten directly as a snack. Consumption of legumes in these forms and at the unripe stage offers a much lower nutritive value and their contribution to dietary protein is likely to be less significant (Verma 1964; Jadham et al. 1960; Patwardhan 1962). The mature legume grain is of greater interest to food scientists from the standpoint of processing.

Milling

Food grain legumes are consumed in various forms usually involving the removal of the seed coat from the cotyledon. Lal et al. (1963) fractionated chickpea and determined the chemical composition of its seed coat, embryo, and the cotyledon. The results indicated that the seed coat which constitutes 15% of the whole grain contains insignificant amounts of other nutrients except for calcium (1000 mg/100 g; Table 4). The cotyledon which makes up 84% of the grain carries an even distribution of nutritive constituents. On the other hand, the embryo is the richer fraction but represents only 1% of the grain.

These findings indicate that the removal of

the seed coat and the embryo during milling will not greatly depreciate the nutritive value of milled chickpea.

Zimmerman et al. (1967) removed successive surface layers of chickpea cotyledon to determine the concentration gradients for protein and the anti-nutritional principles in the grain. The outer layer represents 65% of the cotyledon and it contains 26% crude protein. The inner layer contains 19% protein while constituting only 25% of the grain. The implication for controlled fractionation of the cotyledon to separate protein-rich particles which can be suitable for specific food use appears feasible.

Singh et al. (1968) analyzed the chemical composition of various grain fractions of pigeon pea, cowpea, and mung bean. The seed coat contains about 60% crude fibre and over 50% of the calcium content of the whole grain (Table 5). The cotyledon, being the largest fraction of the grain, accounts for a significant part of the food value of the whole grain. And since the seed coat is composed mainly of cellulose, dehulling will significantly improve the digestibility of legumes while not significantly affecting their food value (Stanton et al. 1966).

The most popularly used and versatile form of processed grain legume is in the dehusked split form (dahl). From this primary processed stage the dehusked split legume grain

TABLE 4. Chemical composition of the seed coat embryo and cotyledon of chickpea.

Chemical composition	Grain fractions			
	Seed coat	Cotyledon	Embryo	Whole grain
Proportion of grain %	15.0	84.0	1.0	100.0
Protein % (N $\times$ 6.25)	3.0	25.0	37.0	21.0
Ether ext. %	.2	5.0	13.0	5.0
Ash %	3.0	3.0	5.0	3.0
Crude fibre %	48.0	1.0	3.0	9.0
Carbohydrates % ^a	46.0	66.0	42.0	63.0
P mg/100 g	23.0	290.0	744.0	272.0
Fe mg/100 g	8.0	5.0	11.0	6.0
Ca mg/100 g	1000.0	70.0	110.0	200.0

^aCalculated by difference.

TABLE 5. Chemical composition of the grain fractions of pigeon pea, cowpea, and mung bean.

Chemical composition	Grain fractions								
	Seed coat			Cotyledon			Embryo		
	PP ^b	CP	MB	PP	CP	MB	PP	CP	MB
Proportion of grain %	16.0	11.0	12.0	83.0	87.0	86.0	2.0	2.0	2.0
Protein %									
(N × 6.25)	7.0	11.0	11.0	24.0	27.0	27.0	48.0	44.0	53.0
Ether ext. %	0.3	1.0	1.0	4.0	2.0	3.0	14.0	10.0	9.0
Ash %	4.0	3.0	3.0	4.0	3.0	3.0	6.0	4.0	4.0
Crude fibre %	32.0	26.0	26.0	0.4	0.3	0.5	1.0	2.0	1.0
Carbohydrate % ^a	59.0	59.0	60.0	67.0	68.0	66.0	31.0	40.0	32.0
P mg/100 g	31.0	89.0	36.0	423	496	341	890	829	756
Fe mg/100 g	10.0	12.0	17.0	6.0	6.0	6.1	13.0	20.7	23.0
Ca mg/100 g	917	853	812	176	165	115	400	368	492

^aCalculated by difference.^bPP, pigeon pea; CP, cowpea; MB, mung bean.

may either be cooked for immediate consumption or further processed into a meal or into refined flour.

The Central Food Technological Research Institute, Mysore City, India, has initiated research interest into the milling of the food legumes cowpea and pigeon pea (Kurien and Parpia 1968). The efficiency of two methods of processing dehusked and split grain legumes was critically analyzed to obtain some guidelines for process and machinery modification.

Milling of legumes is basically a traditional household procedure involving a series of time-consuming, labour-intensive, complex and inefficient processes. An average process requires 3–5 days or even longer to complete depending on weather conditions. A similar process is used for several grain legume species with appropriate modification in the length of tempering time dictated by the degree of adherence of the seed coat to the cotyledon. In general, pigeon pea and cowpea are more difficult to dehusk than chickpea and mung bean. This has been postulated to be due to the high lignin content between the seed coat and the cell walls of the cotyledon which acts as a binding substance (Müller 1967). Loosening of the seed coat prior to dehusking and split-

ting is achieved by either the wet method or the dry method.

The Wet Method The wet method involves tempering the grain with water for 4–12 h and subsequent coating of the grains with red earth and then sun-dried. This process allows the cotyledon to shrink creating a space at the surface of fusion and between cotyledon and the husk. Soaking in water does not facilitate significant transmigration of the nutrients (Lal et al. 1963). Liener (1962) indicated that physiologically active nutritional stress factors in grain legumes are generally eliminated by soaking and subsequently discarding of the soak water.

The shearing action of the rotating plates in the wooden and stone chakkis splits the grain while simultaneously relieving the husk. The husk is then aspirated. This process produces 95–98% dehusking and splitting efficiency (Kurien and Parpia 1968). However, the undesirable effect of the wet method is the longer cooking time required which has always been a critical economic factor in its acceptability to the low-income consumer.

The Dry Method In the dry method, the grain is sorted for uniform size prior to pitting

or scratching of the seed coat with an emery roller. The pitting facilitates the penetration of oil between the seed coat and the cotyledon. The oil-tempered grain is sun-dried and subsequently sprayed with water to soften the seed coat. When passed through a roller mill, simultaneous dehulling and splitting occurs. However, only 40–50% of the grain is dehulled and split during the first pass, necessitating repeated passes to complete the process for the remaining grain.

In Africa, cowpeas are steeped in water to allow the seed coat to swell and loosen from the cotyledon. By gently pounding or by rubbing the grains together, the seed coats become disengaged and float on the water surface where they can be skimmed off. The dehulled grain is then spread out for sun-drying. Another method in common practice involves grinding of the whole grain followed by soaking the meal in hot water to allow the seed coat to float and be discarded. The resultant cowpea dough may either be used immediately as a food ingredient or fermented for future use. Because the seed coat of pigeon pea adheres tightly to the cotyledon, the grain is often parched and subsequently pounded to disengage the seed coat.

Meal and Flour

Further processing of dehulled and split grain legumes into meal or flour is accomplished by hammer milling. The degree of refinement of the flour varies with its specific use in traditional recipes and no doubt will influence palatability and digestibility characteristics.

No known grading standards and quality control procedure have yet been established except for those arbitrarily established by the local consumers. For example in India, deep yellow-coloured split grain of pigeon pea or cowpea is considered superior to white or pale-coloured grain. Consequently, the split grains are polished with a solution of tumeric and water to provide the product appearance the consumers are looking for.

In Southeast Asia, mung bean flour is processed by wet starch extraction. The bean is

soaked overnight to loosen and facilitate removal of the seed coat. The dehulled beans are then rasped and passed through a fine mesh to separate the cellulose. The slurry is then allowed to settle in starch tables for 6–12 h. After sedimentation has occurred, the wet mung bean starch is repeatedly washed prior to using in mung bean noodle manufacture (Zamora and Garcia 1973). Valuable protein is washed with the waste-water. It seems logical that the protein in mung bean can feasibly be fractionated from the flour prior to its use in noodle processing, or alternatively the protein by-product can be recovered from the waste-water.

Milling Characteristics

Owing to the lack of empirical data on the factors affecting the milling characteristics of grain legumes, the available information is primarily based on reported experiences in milling operations.

Kurien and Parpia (1968), in their study of the milling of pigeon pea, observed that the ease with which the grain was dehulled, split, and further processed into flour appears to vary with differences in grain variety, the agronomic conditions upon which they are grown, and the seasonal variations. The presence of lignin between the seed coat and the cell-walls of the cotyledon may also be a factor (Zimmerman et al. 1967).

The conformation, seed size, seed maturity, and uniformity of the grains affect the milling efficiency. Normally, plump and uniform-sized and mature pigeon pea, commonly grown in central India, facilitate efficient dehulling with simultaneous splitting of the grain. Conversely, the variety primarily produced in northern India, which are small in size, are more difficult to dehull and resistant to splitting. Perhaps due to the larger surface area exposed to abrasive decortication, the plump and mature grain adapt better to the dehulling machine than the tiny grains. Seed coats of winter crops were found more difficult to disengage from the cotyledon than those harvested during other seasons. Reasons for this phenomenon could not be found in the literature.

Traditional milling operations may appear deceptively simple, but the series of complex steps in preparation which are meticulously undertaken in proper sequence and at specified times and duration have evolved through many years of tradition to generate the right grain characteristics for suitable milling. The justification for each sequential processing step (i.e. timing and duration of soaking, washing, overnight heaping, etc.) and their interplay with identifiable factors affecting grain milling characteristics warrants scientific investigation.

Cooking Quality

The major disadvantage in the utilization of grain legumes is the extended cooking time needed to achieve the desired palatability and digestibility characteristics. This increases the fuel required for cooking which is not readily available in developing countries.

McCance and Weddowson (1960) reported that phytic acid present in certain grain legumes renders the Ca and Fe insoluble, thus making them unavailable for nutrition. This was also suspected to cause the hardness of cooked legumes. Müller (1967) indicated that the hardness of cooked legumes is influenced by the interplay of their phytic acid, Ca, Mg, and free pectin content. Softening of the grain occurs through a reaction of phytate (present as Na/K phytate in the cotyledon) with the insoluble Ca/Mg pectate (present in the cell walls and the seed coats) converting Ca/Mg pectate to soluble Na/K pectate. On further investigation, results showed that hardness has no correlation with the starch content and the amylose/amylopectin ratio present in the grain. Even if progressive cooking did facilitate the swelling of the starch granules, the cell walls remained intact and the cells tightly bound together (Müller 1967, Kurien 1971).

Correa et al. (1965) reported that the restricted swelling power of chickpea starch could be partly due to the fat bound within the starch granule and perhaps primarily due to the intense binding forces that exist inside the granules.

Tolmasquin et al. (1965) indicated that chickpea starch is naturally cross-bonded which shows neither viscosity peak nor fragmentation during cooking. However, defatted chickpea starch showed a rise in viscosity as the pH of the medium increased. These findings may have important food use implications when considering chickpea in legume-based food forms.

Heat application such as in parching or autoclaving may be beneficial in destroying anti-nutritional principles present in the grain, but in most cases it may reduce the nutritive value of the proteinaceous constituents which are not directly responsible for the anti-metabolic activities after legumes are ingested (Liener 1962). Mung beans on the other hand appear to improve in biological value and to some extent digestibility after parching (Archarya et al. 1942). Borchers and Ackerson (1950) reported that heat treatment by autoclaving improved the biological value of cowpea but not chickpea and mung bean. No correlation was observed between the effect of autoclaving on the nutritive value and the presence or absence of a trypsin inhibitor in some raw grain legumes. Hirwe and Mugar (1951) found improvement of nutritive value in autoclaved pigeon pea.

There appears to be a fair degree of inconsistency of results among workers on the effect of heat treatment on the biological value, anti-metabolic activities, and the digestibility of similar or varying species of grain legumes (Sherman 1940; Sherwood and Weldon 1954; Finks et al. 1922; Zimmerman et al. 1967). More study is required to identify other factors that might cause grain legume species to react differently to similar heat treatment.

Quick-Cooking Grain Legumes

At the Western Regional Research Laboratory of the US Department of Agriculture in California, a simple convenient process has been developed for the preparation of various types of quick-cooking products from grain legumes cooked within 15 min, an 80–90% reduction in normal cooking time (Rockland et al. 1970).

The process involves the loosening of seed coats by intermittent vacuum infiltration (Hydrovac process) or by blanching with steam or hot water. This is followed by soaking of the grain in a solution of common inorganic salts including sodium chloride, sodium tripolyphosphate, sodium bicarbonate, and sodium carbonate.

The Hydrovac process induces infusion of the salt solution through the hilum and fissures of the hydrophobic outer layer of the seed coat. Wetted by the salt solution, the inner membrane hydrates rapidly, plasticizing the seed coat causing it to swell to maximum size in a short time.

Based on the assumption that legume proteins influence the texture and cooking characteristics of cotyledon, hydration media were intended to disperse or solubilize proteinaceous constituents. Metal agents such as phosphates were added to it in dissociating possible Ca or Mg or other metal salt-protein complexes and to prevent discolouration due to contact with metals such as copper and iron during processing.

Sodium chloride decreased the cooking time for the seed coats and slightly increased it for the cotyledon. It also intensified and improved the natural legume flavour.

The quick-cooking legumes had smooth and uniform texture, enhanced natural flavour and excellent colour and general appearance. No significant differences in their nutritive value were detected compared to corresponding products prepared by conventional methods.

Balanced Food Mixtures

A fairly recent use of food legumes is in a balanced food mixture with cereals and other food material of high nutritive value. This has provided a convenient form of food for the children in the vulnerable age-group and for expectant and nursing mothers.

Indian Multi-Purpose Food (IMPF) has been developed at the Central Food Technological Research Institute, Mysore, India, as a supplement to high carbohydrate diets (Parpia and Subrahmanyam 1959). It contains

49% protein provided by 25% chickpea flour and 75% groundnut meal. Sesame seed flour has been recommended as a methionine fortification. The supplementary essential amino acid content of both ingredients makes IMPF a food of high biological value. It is versatile in its food use properties which makes it a very suitable ingredient in breads, sweets, and porridges.

Another food form similar to IMPF is the Supermine. It consists of 25% wheat flour, 38% chickpea flour, 19% lentil flour, 10% skimmed milk powder, and 5% sugar. Though not as versatile as IMPF it has provided an excellent weaning food.

In Chile and in Lebanon mixtures based on 80% precooked chickpea flour and 20% skimmed milk powder are currently being used in infant feeding trials. If the results of the study show excellent tolerance to the diet of the mixture with consequent improvement in the nutritional status of the infants under observation, the formula will be produced on a larger scale for wider consumption. What will find wider useful application is the development of food mixtures using acceptable home preparation methods.

Other Potential Food Forms

A common nourishment feature in South-east Asia is soybean milk. The process is still a traditional and small-scale operation. Split soybean is hydrated for 4 h in dilute alkali (sodium hydroxide) to remove the seed coat and to render the bean more digestible). The beans are drained and washed several times prior to grinding. The resultant slurry is filtered through a cheese-cloth and diluted in three parts of water prior to boiling. With the addition of sugar, soymilk becomes a very highly acceptable beverage.

Soybean curd (*taukua*) and soybean gel (*tau-huay*) are two other forms in which soybean is widely consumed in the region. *Taukua* is used for ingredients in main dishes or soups while *tau-huay* is used for dessert. Both products are produced by boiling the soybean slurry and precipitate it with magnesium or calcium salts. These processes now strictly

used for soybean could find useful application for other food legume species.

In Indonesia fermented food forms such as *tempeh*, *ont jam*, and *rage* are very popular. They are made from peanut, soybean, or any leguminous press cake inoculated with *Neurospora sitophila* or *Rhizopus* spp. The resultant fermented cake can either be fried or steamed prior to consumption.

In India, grain legumes are used in curries and soups and they also constitute the main ingredient in *papads*, *chapatis*, and in fermented dough such as *dosa* and *idlie*.

There are many ways food legumes are used in different parts of the developing world. Each form of food indigenously developed offers food preparation principles which could have wide application. Investigations along these lines have already started in Canada.

At the Prairie Regional Laboratories of the National Research Council and the University of Saskatchewan in Canada, the IDRC has provided support for studies on the nature and size of starch granules in some legumes which have already led to some interesting findings. By abrasive decortication followed by controlled hammer milling of the cotyledon, the starch granules can be extracted from the protein matrix. Further separation of the protein fractions can be achieved by air classification in which the legume flour is subjected to a centrifugal force opposed by a centri-pilot air drag. If this research is successful, it offers a tremendous promise in the development of protein-rich foods for the vulnerable age-groups.

Food legumes should no longer remain a subsistence crop. Grain legumes offer a bright future for the development of various food forms of high biological value.

Conclusions

To develop sound research priorities on the processing and utilization of grain legumes, the first recommendation is a comprehensive survey of traditional preparation procedures for food legumes, with a critical analysis of the problems involved, the economics of the systems, and the nutritional implications. With

some realistic basis the functional properties demanded of grain legumes may be identified for specific food forms.

Research is required to identify appropriate milling characteristics, improved milling techniques and technology. Research on anti-nutritional and digestibility factors is essential to make grain legumes a suitable and more acceptable food for the weanling children. Finally, research on new food forms that can serve as a source and a vehicle for high-quality protein warrants special consideration.

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SESSION IV PAPERS

Food and Agriculture Research and Industrial Development

Anuwar bin Mahmud, Chairman



Current Status of the Padi and Rice Industry in Malaysia

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Abstract The padi and rice industry in Malaysia are reviewed, including the important social and economic implications of the industry. Government policy regarding production of padi and rice had three objectives: to support farm incomes, to reach self-sufficiency levels, and to ensure a quality product at reasonable cost to the consumer. More recently, emphasis has switched to other cash crops suitable for padi lands (e.g. maize, sorghum, tobacco, groundnut, and sugar cane), and an adjustment of the self-sufficiency requirement to 90% of domestic requirements. The Price Support Program is discussed and the problems of the off-season harvest are reviewed.

Résumé L'auteur passe en revue les modes de production du paddy et du riz en Malaysia, y compris les implications économiques et sociales de cette industrie. En ce qui concerne la production du paddy et du riz, les politiques gouvernementales sont orientées vers trois objectifs: soutenir les revenus agricoles, atteindre l'auto-suffisance et assurer la fourniture aux consommateurs de produits de qualité à des prix raisonnables. Les autorités s'orientent depuis peu vers la promotion d'autres cultures marchandes adaptées aux terres à paddy (p. ex. maïs, sorgho, tabac, arachides et canne à sucre) et vers la couverture par la production nationale de 90% des besoins intérieurs. L'auteur analyse le programme de soutien des prix ainsi que les difficultés que pose la récolte hors-saison.

RICE is a complex and wide subject. With the world rice crisis still on the horizon, anybody who speaks about rice at an international symposium may be accused of being responsible for the present rice shortages and high prices. That is why, I think, nobody now wants to talk about the Green Revolution.

I will therefore confine my comments to some social and economic issues which are common to all rice-producing countries in Asia.

I would first like to explain briefly the present situation of the padi and rice industry in Malaysia.

Background of the Industry

Rice is the staple food in Malaysia. It comprises more than 20% of the food consumed by the entire population, and makes up as much as 35% of the diet of rural people. Next to rubber, the cultivation of padi is the most im-

portant agricultural activity in the country in terms of employment and land utilization. The total area under padi in 1973 was about 1.143 million acres; the actual planted area fell short of this figure. In 1970, about one third of the padi acreage was planted with two crops per year, and by the end of 1975, it is estimated that nearly two thirds of the area will be double cropped.

The *rice production* in 1973 was estimated at 1.231 million tons. The average yield from the main season crop is a little more than 1 ton of padi per acre; while the second or off-season crop is higher by about 300 lb. The annual rate of increase of padi production is 5.4% or 32,000 tons of padi per annum and is mainly due to the increase in the double-cropped acreage and the improvement in padi yields.

Food consumption surveys have not been carried out in Malaysia. However, based on the "crude consumption rate" of 280 lb. per head per year, the rice consumption was about 1.427 million tons last year as against the estimated production of 1.231 million tons, giving a national self-sufficiency level of 86.3%. Per capita consumption is expected to decline over the next decade. As incomes rise, there is likely to be a gradual decrease in the consumption of rice and an increase in consumption of wheat, higher value protein foods, fruits, and vegetables.

There are about 380,000 *farm families*, half of whom cultivate an average of 2-5 acres of land per family and earn a net cash income between M\$45-110/month (in 1973). Many of them have fragmented holdings and cultivate on two or more pieces of land. The 1960 Census of Agriculture indicates that 25% of padi farmers worked on two parcels and 19% on three and more.

With regard to *land tenure*, it is estimated that 60% of the padi lands is operated by the owners themselves while the remaining 40% is rented out to tenant farmers under various arrangements ranging from fixed rent in cash or padi to crop sharing.

About 60% of the padi produced is marketed and this percentage is higher in double-

cropped areas because of the lack of storage facilities and the need for cash.

Government Policy on the Industry

Government policy on padi and rice is an integral part of the overall national policy — The New Economic Policy — that of restructuring the Malaysian society and eradication of poverty among all Malaysians.

The objectives and modes of implementation of this policy have undergone changes in the last few years because of changing domestic and international rice conditions.

In the past, rice policy had three general objectives: (1) to support farm incomes; (2) to promote rice production to self-sufficiency levels; and (3) to ensure consumers of quality rice at reasonable prices and at minimum cost to the government.

Through the mechanism of a guaranteed minimum price scheme (GMP) for padi (introduced in October 1949), these objectives were reasonably achieved for there has been a steady increase in rice production mainly owing to the success in double crop programs and increase in padi yields per acre. But the past objectives were critically reviewed as *self-sufficiency in rice for the country would not necessarily enhance farmers' incomes to a satisfactory level*. It would, on the other hand, create problems of price support and rice smuggling into Malaysia unmanageable, since the domestic price was then 50% higher than the international market price.

In 1971, the objective was revised from one of self-sufficiency per se to that of enhanced incomes and welfare of padi farmers through increased yields on existing acreages and development of new crop possibilities suitable for padi lands (e.g. maize, sorghum, tobacco, groundnut, and sugar canes) which offer maximum net returns. Taking into account economic and social factors such as domestic price support, storage facilities, international market price, and consumer preference for foreign rice, it was then considered that the ideal production level was at 90% of domestic rice requirements. Thus, until lately, Malaysia's aim was to produce 90% of her rice require-

ments and to import the balance from her traditional suppliers. In order not to increase local production of rice beyond this level, the government decided that no new padi land be opened through public investment in irrigation facilities under the Second Malaysia Plan 1971-75.

In early 1973, the world experienced the most unexpected reverses in agricultural production. Adverse weather conditions and ravages of war resulted in supply shortages of all food-grains throughout the world. Consequently the price of rice in the world market rose by more than 100% (and has increased even more in 1974). But even at that price, Malaysia could not get sufficient quantity from her traditional rice exporting countries.

The danger of depending on other countries for essential commodities has become very apparent, and under the circumstances, reversal to the previous objective of self-sufficiency was inevitable. The government has therefore recently revised its 90% objective to an objective of full self-sufficiency and is taking steps to open up new land for padi cultivation.

The present self-sufficiency objective has to be consistent with the farmers' income and welfare objectives, and this is a challenge to policy implementers. The present situation in the world market has brought many imponderables and unknown variables that might make an excellent formulated plan go awry. For instance, one may ask: "Which way would the present high prices of food-grains go? How long would the shortages of food-grains last? To what extent would other factors, such as inflation and the oil crisis, affect prices and supplies of rice and other food-grains? How would the proposed international rice buffer stocks work and its relationship with national buffer stocks? How would the supply of fertilizers be affected by the oil crisis? What is being done to reduce dependence of padi yields on fertilizers to meet the fertilizer shortages?" Answers to these and other similar questions form a basis for planners of economic development and researchers to advise the government.

Role of the Public Sector

Traditionally the poorest sector of the rural community, the socioeconomic position of padi farmers in Malaysia has been improved substantially over the past decade by government programs to expand rice production. These programs have included very heavy investment in irrigation facilities, especially with regard to double-cropping, applied research, extension programs, the implementation of a guaranteed minimum price, and provision for production credit.

In order to ensure full coordination of government efforts and direct implementation of certain specific programs, a statutory body called the National Padi and Rice Authority was established by the government in September 1971. The Authority is intended to be a single integrated agency responsible for the formulation of overall national policies for the rice industry, and has been assigned the specific responsibility of ensuring fair and stable prices for both producers and consumers and of ensuring sufficient supplies of rice to meet any contingency.

The Authority was established at a time of rice surplus in the world market with its price far below the domestic price. It was a time when the Green Revolution had influenced the minds and actions of national economic planners and implementers with regard to agricultural development. It was a time when thought was given to the income and welfare of farmers and very little to rice consumers. For a high-cost producer like Malaysia, the prospect of becoming a rice-surplus nation was indeed alarming. It was against this background that Malaysia set a production target of producing only 90% of her requirements. But the world rice situation suddenly took a sharp and sudden turn in early 1973. This situation of rice shortages and high prices remained over a year, and the Authority, and for that matter, all such bodies charged with similar responsibilities such as BULOG of Indonesia and N.G.A. of the Philippines, have indeed undergone a tough time.

These reverses in the world grains situation of over one year now might easily form a

basis for long-term agricultural planning by national governments, and if these supply shortages and high prices turn out to be short-term events, we might then be faced with a different form of food-grain crisis before the end of this decade.

For the moment, I would like to discuss certain problems which are least affected by short-term events in the world rice market. Two aspects come to my mind: one relates to the price support program and the other is off-season harvest. I have had both the pleasure and the displeasure of implementing programs relating to both.

Price Support Program

The rationale behind the price support is to prevent the price of padi from falling too low both seasonally and over a period of time. The underlying argument is that the demand for padi and rice is fairly inelastic in the short run and an increase in supply in relation to demand would cause a disproportionate fall in the price. Another reason is that a fairly high guaranteed minimum price (GMP) provides an incentive to greater domestic production.

The GMP for padi in Malaysia was introduced in 1949 at M\$15/picul for dry and clean padi delivered to the mill. The level of the GMP remained fairly stable at \$16 until 1973, when, with a sudden increase in the price of padi well above the guaranteed price, the support price has been "floated" in order to be in line with the price of rice in the domestic market. Officially, the GMP still remains at M\$16 but the present unofficial support price is M\$22-26/picul of padi depending on variety. The "floating" of the support price is intended to ensure that the big increase in the domestic price of local rice will also benefit padi farmers. If the GMP had remained at \$16, the private padi buyers and millers would only buy padi at a price just above the official price, even though the present price of rice justifies them to buy padi nearly double the price. At the same time, the Authority is hesitant to recommend to the government the new level of price support as

official since the factors affecting the present high price, as I have already mentioned, might be only temporary phenomena.

The greatest danger of any increase in the level of price support is that it may become permanent even though the reasons justifying it are no longer valid. It would be very difficult to reduce a guaranteed price; instead, such increases are liable to escalate. The whole matter may also become a political issue.

If the present (early 1974) international market price for rice remains high, the level of price support in Malaysia is still comparatively low. On the other hand, if it plunges to the level of 1971, the Malaysian rice will be 150-200% more expensive than the imported rice. This means that in the event of a local production surplus, a huge subsidy would be required to move any exportable surplus from Malaysia into the world market.

The purpose of a price support should not be merely to put ever-increasing sums of money into the pockets of farmers without regard to their standards of production. Price support should help the farmers to improve production — both in quality and quantity — so they can obtain higher returns from their produce in the open market. In the long run, the domestic prices should even be reduced to near world levels.

These improvements are unlikely to be obtained as a result of the guaranteed price alone. There have to be other services, research and extension work, better farm practices and, above all, land reforms.

Existing padi farms in Malaysia average 3.1 acres. Only 15% of padi farmers operate farms exceeding 6 acres. There are subsistence farmers who have no surplus of padi for sale because of the small size of their farms.

The problem of uneconomic holdings and subsistence farmers is found both in single as well as double-cropped areas, and cannot be solved by the price support program alone. Possible solutions lie in measures that would increase their incomes by such means as increasing the farm size, moving the subsistence farmers to new areas and consolidating the land, intensifying cultivation, and increasing off-farm incomes. These measures are being

seriously studied in Malaysia, and the Authority is also an agency to assist government in their implementation.

Padi Drying Facilities

It was thought that double-cropping would double the income of padi farmers. It has not worked out that way, although many who earlier were subsistence farmers now have a surplus to sell. The extension of irrigation facilities and the introduction of high yielding varieties have substantially changed the cost-price structure of padi production under double-cropping conditions.

One major problem of harvesting of the off-season crop is the drying of padi. With double-cropping, padi is harvested in wet-weather conditions. If the padi is not dried immediately after harvest, it starts germinating and loses weight. The farmer will get a poor price for his padi and this will inevitably result in dissatisfaction. The high moisture content of the padi that is sold provides opportunities for buyers to make arbitrary deductions for moisture. These excessive deductions discourage farmers from drying their padi even on days when there is no rain.

It was originally envisaged that artificial drying facilities would be automatically provided by private millers. This turns out to be a wrong assumption. Private mills are normally operated on credit and find it difficult to justify large investments (ranging from M\$1.7 million for a dryer of 10 tons/h to M\$1.10 million for a smaller 3-ton dryer) on services which they could neither readily charge the farmer nor the consumer to allow reasonable returns on their capital outlay. Whatever drying facilities that private millers have installed come in as appendices to their mills, and the total

capacity of these fall short of off-season requirements.

For these reasons, the Authority has been given the task of ensuring that there are sufficient drying facilities in all double-cropped areas. It has to be its responsibility anyway, because padi farmers can always pass on the unsold wet padi to the Authority under the GMP scheme.

The problem does not end here. The dryers are utilized only about 2–3 months in a year, and it costs M\$2.38 to dry and keep one picul of padi. A question thus arises as to who should pay this cost of drying and what should the drying complex and the employees be doing for the rest of the year. One solution is to attach mills to artificial drying complexes so as to make them viable and economical to run and maintain. The effective drying cost will then be drastically reduced. It was estimated in 1973 that for every picul of rice that is sold after drying and milling, the Authority would lose M\$1.08, after taking into account 6% interest rate, depreciation, and reasonable returns on the capital outlay. However, if only depreciation and capital outlay are considered, the Authority would be able to make a profit of M\$0.84 per picul of rice.

The National Padi and Rice Authority now has 14 drying and integrated complexes in operation, and after mid 1974 another six will be ready for operation. More are being constructed. Each complex costs about M\$4.5 million.

But as in the case of many public programs, one of the major constraints in achieving the objective is lack of trained personnel at all levels.

I recognize that the problems I am now experiencing are common to all countries in this region, and I am confident the sharing of experiences provided by this symposium will help to solve some of the problems.



Development of the Dairy and Livestock Cooperatives in India

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Abstract The main problem in food and agriculture in India and other developing countries is not identifying what *should* be done but *how* to get it done. One way might be through the experiences of the dairy and livestock subsectors. The Kaira District Co-operative Milk Producers' Union now has annual sales of over \$50 million, with a membership of 235,000 producers in 785 primary societies covering 2500 square miles. In addition to producing a full line of dairy products, the Union owns and operates a cattle-feed compounding plant and an artificial insemination system for members. It also operates a veterinary care and extension service employing veterinary doctors, and other specialists. The development of the union is described and recommendations are made to make research more responsive to the economic and social needs of developing countries.

Résumé Que ce soit sur le plan de l'agriculture ou sur celui de l'alimentation, le principal problème de l'Inde et des autres pays en voie de développement n'est pas de définir ce qui *devrait* être fait, mais *comment* arriver à le réaliser. L'expérience des sous-secteurs du lait et du bétail peut être fort précieuse à cet égard. L'Union coopérative des producteurs de lait de la région de Kaira a maintenant un chiffre de vente supérieur à \$50 millions, et compte 235,000 producteurs membres répartis en 785 sociétés de base couvrant un secteur de 2500 milles carrés. Outre le fait qu'elle produit une gamme complète de produits laitiers, l'Union possède et gère une usine d'aliments du bétail et un système d'insémination artificielle réservés à ses membres. Elle assure également un service vétérinaire (soins et vulgarisation) et emploie à ce titre des vétérinaires et autres spécialistes. L'auteur décrit le développement de cette union et fait des recommandations visant à orienter davantage les recherches vers la satisfaction des besoins économiques et sociaux des pays en voie de développement.

A Framework

The links between the "Interaction of agriculture with food science" as a whole, and "Food and agriculture research and industrial development" are so complex and numerous that it would be a lengthy and tedious process to try to establish them here. Instead, I am suggesting that three assumptions may first be

accepted, at least initially, for the purpose of getting to the main argument of this paper:

My first assumption is that we have yet to establish what is meant by "industrial development" for countries like India. Industrial development is usually considered a concept which grew out of the European and American experience in the last century. It is necessary for the developing countries to recognize

that "industrial development," as the West sees it, is not feasible in most developing countries, at least for many years. In any case, it may not be suitable or desirable for our societies. For example, many (so-called) developed countries are proud of the fact that only 5% of their population are directly involved in (dependent) agriculture. India will soon have a population of some 800 million people. Does "industrial development" imply that we will have some 760 million people living and working in an urbanized, industrially developed society, with the remaining 5% (or 40 million) directly working on the land? Even if it were feasible, such an excessive urbanization would be socially undesirable. In fact, we do not have enough capital to create the number of industrial jobs that such a monstrous urbanization would call for. Thus, our industrial development must not and will not take the same shape as in the West.

My second assumption is that "food and agriculture research" is one of the ways by which a modernizing society uses science to enable the food agriculture sector to serve the ever-increasing social needs of society. It does this by helping to improve the "linkages" between producers and consumers. The linkages include the processes of conversion, whereby energy is converted into food, sometimes in a fairly direct manner for the production of vegetable foodstuffs, and via production of vegetable foodstuffs for animal products; also included are such factors as the economics of exchanges between producers and consumers, and the institutional arrangements whereby food producers exchange at least some of the food they produce for goods and services from consumers. Thus, food and agriculture research serves the social objectives of society by scientific study not only of food technologies, but also of the economics and the institutions which comprise agriculture food systems.

My third assumption is that developing countries are not yet capable of making full use of food and agriculture research. Some developing countries have been following the same food and agricultural research programs as the developed countries, emphasizing energy

food conversion techniques which use more oil than the world is either prepared to or able to supply. Our countries have failed so far to develop their use of food and agriculture research to any significant extent, and that, indeed, is the problem which I want to emphasize here.

Getting Something Done

No doubt, some food and agriculture research which has been conducted in and for the developing countries has been useful, but our main problem in the food and agriculture sector at the moment is not that of identifying what *should* be done but how to get it done.

However, I believe that we have found a way (though not necessarily the only way) of getting something done in the dairy and livestock sub-sector. The first example is the Kaira District Cooperative Milk Producers' Union. This cooperative began before India's Independence as a protest movement against an alien dairy company which may have been exploiting milk producers of the district. Last year the cooperative's sales totalled Rs. 392 million (about us \$50 million). But more important than its size is the Union's institutional structure. It has a membership of 235,000 milk producers in 785 primary societies covering 2,500 sq mi.

It is organized on a village-by-village basis. When the producers in a village decide that they want to handle their milk business cooperatively, they form a milk producers' primary cooperative society. Every family can join it, provided they sell only their own milk to it. The society is managed by a paid, professional secretary, who is trained by the Union, and according to its size, it also employs trained clerks, milk testing staff, etc.

Milk producers bring their milk to the society each morning and evening. The milk is measured, sampled, and subsequently tested for fat content (the Union conducts some 185,000 fat tests morning and evening) and the producer is paid for his morning milk in the evening and for his evening milk the following morning.

Milk from the societies is picked up each morning and evening by trucks, which carry it directly to the Union's dairy plant. This plant is owned by the Union which, on behalf of its producer-members, hires professional managers, marketers, technical personnel, etc. The Union has a full line of dairy products, including cheese, pasteurized butter, baby food, etc. Its use of modern marketing techniques has enabled it to become a leader in its field and to earn an annual bonus of 10% for producer-members on their milk. However, of equal significance, is the fact that the Union's marketing is a "two-way street": it owns and operates a cattle-feed compounding plant and an artificial insemination system for the members. As much as 250 tons of cattle feed are marketed daily through the Union's 785 primary societies—and some 200,000 artificial inseminations are carried out yearly by inseminators employed by the primary societies.

The Union also operates a veterinary care and extension service, employing 42 veterinary doctors, green-fodder extension specialists, cooperative business advisers, etc. They visit all the villages weekly, and provide a 4-h emergency service.

Thus, the Cooperative works not only to provide a direct and consumer-oriented channel for the producers' milk, but also as the marketer of technical inputs to help the producers improve their milk production. The Union's milk production services come out of its revenues (they cost the equivalent to approximately one US cent per gallon) and therefore place no burden on State funds.

The Union's Project Division has helped milk producers in other districts to form similar cooperative unions. Altogether, there are six such unions in the state with processing plants capable of producing a balanced line of milk products—and these have now formed the Gujarat Cooperative Milk Marketing Federation, to enjoy the benefit of common marketing facilities for their products.

This development is especially important when one considers that the Kaira Cooperative alone sends as much as 200,000 litres of liquid milk daily to Bombay (some 300 miles

south) and other members of the Federation have shipped liquid milk as far as Delhi (some 600 miles north). In other words, the Federation's dairy plants constitute the beginning of our National Milk Grid.

Moreover, the Project known as "Operation Flood" is helping to set up some 18 "Anands," India's major milksheds, *plus* storage and long-distance transportation facilities for liquid milk and preserved milk solids. The system as a whole will be able to feed these into the National Milk Grid, to even out seasonal and regional imbalances between supply and demand, thereby stabilizing urban milk supplies and providing a sound foundation for our modernizing dairy industry.

Thus, the system benefits urban consumers, while also feeding back technical inputs to help milk producers improve their milk production—and these benefits do not go only to the wealthier farmers. On the contrary, most of our milk producers have only one or two buffaloes and less than 2 acres of land. The system enables them to more than double their incomes through milk production. Indeed research shows that, by the Anand Pattern, the poorest 40% of milk producers get the benefit of more than 40% of the income earned through the cooperative marketing of milk in the Region.

The Green Revolution

The picture presented by the Green Revolution is very different. Although it is true that the high-yielding varieties of wheat and paddy have enabled the country to increase its production of staple cereals to the point when the country can expect to be self-sufficient in these crops, nonetheless the benefits are most unevenly distributed.

In 1970-71, for example, the new high-yielding varieties of rice and wheat were probably grown on some 20% of rice-land and wheat-land—that would have been 7-8% of the total area sown. Adoption of the new varieties which are the basis of the Green Revolution is limited to the farmers who have the most resources, access to credit, and able to absorb risk. This means that the fortunate

few are the chief beneficiaries. Indeed, a detailed study in one area, where intensive efforts had been made to popularize high-yielding varieties, showed the poorest 40% of rural people to be getting less than 20% of the additional income created by these new varieties, while the top 60% got over 80% of the extra income! In another area, the poorest 30% of farmers ("sub-marginal" farmers, with less than 2.5 acres of land) accounted for less than 10% of the additional production gained from high-yielding varieties. However, as it happens, this particular area is a part of the Kaira District — and there, the same small farmers were, in any case, earning more from dairying than from all their field-crops combined.

Minimizing Future Error

To minimize repetition of the errors which have limited the usefulness of the Green Revolution, the future modernization of any part of a country's food-agriculture sector has to evolve a consistent "chain," including not only the new technologies involved, but also their economics — and the institutional arrangements which bring them about. All these elements have to be developed as a set of consistent links between the producers and consumers concerned.

Thus, in India, as we initiate the modernization of dairying, the "chain" which we construct between milk producers and consumers must enable the underemployed masses in our rural milksheds to participate in milk production, applying their family labour to the rearing and management of productive milch animals. We cannot adopt (as past international conferences have suggested) a technology which would simply place highly productive, but extremely delicate and costly milch animals in the hands of richer farmers, on the grounds they alone have the necessary capital and managerial expertise. On the contrary, we have to breed cross-breeds which are hardly enough to survive the lower levels of nutrition and management which must for some time prevail among all but the richest farming families in our milksheds.

Moreover, as much of our population will continue to live in rural and semi-rural communities for some time to come, many will continue to produce milk for their own consumption, selling only to nearby neighbours. The process of dairy modernization must benefit these people — and I believe that it will, because we can see to it that cross-breeds are reared in our milksheds on such a scale that the producers will not retain them all; they will select the best and the remainder will be sold into other rural areas, where they will be far more productive than the milch animals now available. Thus, the productivity of these better converters will spread in a "ripple" effect, creating ever-widening circles of improved milch animals, to the increasing benefit of producers and consumers who will not for some time be brought directly within the confines of our modernized dairy industry.

For those who are within the bounds of the modern industry, the processing part of the "chain" has to be similarly consistent with overall objectives. For example, it is not a productive use of our scarce capital to build elaborate Western-style urban dairies, especially those relying wholly on bottling for packaging and distribution. This is why our National Dairy Development Board is developing what we refer to as a "bulk vending system," which will permit large, efficient dairies ("Mother Dairies") to serve either a large city or a number of small cities with pasteurized, chilled milk. It can be moved by large bulk-tankers to bulk-vending retail points, from where it can be dispensed to consumers in their own containers, thereby greatly reducing the resources required for the system and its costs to our poor producers and consumers. Thus, these Mother Dairies, with their bulk-vending retail outlets, form the urban part of a system which we can afford to duplicate — and which will enable our Milk Grid to serve our poor rural milk producers and our urban consumers.

Note, however, that cross-breeding, bulk vending, long-distance transportation, etc., comprise only the technological aspects of the system. Its economic elements have to include dairy plants which are viable, which can sus-

tain technical-input marketing programs, to help milk producers to improve their milk production, and which can develop and market a line of milk products which will best satisfy consumer needs.

Thus, the institutional elements of the system must be such as to attract highly motivated individuals. In particular it must develop institutions which are sensitive to the poor rural producers' needs. This implies another need: there must be agencies capable of duplicating and improving on successful models for milk production, processing, and marketing, which will also be focal points for the development of improved technologies, management information systems, manpower development services, and economic deployment of financial resources. Without such a set of agencies, successful dairy projects could at best come up only in isolated instances. Our experience indicates that dairy projects cannot continue long in isolation, if only because demand-supply requirements make them interdependent and, in any case, they require an integrated industrial infrastructure for the production of technical inputs, dairy machinery, etc.

The Role of Food and Agriculture Research

I have tried to outline the concepts required to avoid errors which have limited the usefulness of the Green Revolution. To what extent has research assisted us so far in this task?

No doubt the Kaira Cooperative benefited by some work done on breeding techniques, etc., which has enabled us to build up our artificial insemination system. Also, the Union's viability was considerably strengthened by the ability which it developed to make milk powder, cheese, and baby food from buffalo milk.

However, it is also true that we are still using a wet semen system for artificial insemination of buffaloes because (although our modern dairy industry handles mainly buffalo milk) technical problems involved in the use of frozen buffalo semen have still not been overcome. Certain government officials, ex-

perts from our national research institutions, and even international experts, claimed that it would be impossible to make milk powder from buffalo milk. In fact, very little research was required to find out how to make good milk powder from buffalo milk and that we did largely ourselves.

There was the same kind of resistance to our making baby food. In this case, of course, the chorus of protest was joined by the international baby food manufacturers.

Our cheese development, on the other hand, was greatly assisted by an expert whose services we received via an international agency (and who, incidentally, has recently been awarded an honorary degree by our State Agriculture University in recognition of his contribution). But here again, the research which had to be done was carried out largely within the Kaira Cooperation.

Thus, the contribution of research to such success as we have enjoyed in the development of our dairying so far has not been great. Moreover, the contribution of research institutions has been even more limited, since so much of the work had to be done by Kaira Cooperative itself. These facts have to be noted because they help to explain why so much more needs to be done. We have to learn much more about making improved converters, such as cross-breeds, available for milk production by our poor people. We must develop processing methods with low capital requirements — and these will call for new product formulations, new delivery systems, etc. At the same time, we have to develop an effective information system for operating the Milk Grid, to make it sensitive to changes in milk production and consumption in widespread markets, thereby enabling our "chain" to serve the needs of our producers and consumers more efficiently.

The Forces Against Change

With all the money and effort which has gone into dairy development so far, on both a national and international basis, why have we not advanced further in the use of research to develop the tools which we need for the mod-

ernization of our dairying? Why, with reasonably successful models before us, are we only now developing the means of duplicating such models and improving on their success? Why has food and agriculture research contributed little to solving these problems? Surely it is because powerful forces have worked against such change — and may continue to do so. For example:

1. Organizations owned and operated by milk producers are a key instrument for dairy development; but putting such important instruments into the hands of farmers is a crucial institutional change — and our institutions, like yours, are resistant to change. Our administrative structure for such development is a legacy from the country's previous rulers. When Independence came, this administrative structure did not change all that much.

The administrative structure which has thus persisted is highly centralized, everything must ultimately be "referred to Finance" and this does not encourage an adventurous spirit either in such directions as handing over developmental institutions to milk producers, or in encouraging research institutions to undertake innovative research into such institutional changes.

2. The elite of developed and less-developed countries often have more in common with each other than they have with the common man in their own countries. The idea of a rurally-oriented developmental bias may well be inherently unattractive to our elite, for example, whose way of life is urbanized. No wonder, then, that the elite of Europe, America, etc., may find the idea of relying on poor producers to look after their own development almost incredible. Such attitudes also condition how "developmental aid" is given: the bureaucracies of aid-giving countries feel much more comfortable when talking to bureaucrats of aid-receiving countries — so both are happy to agree they should only talk with each other, rather than, for example, bringing farmers' organizations into the act.

3. One must also consider the moves to make deficit countries dependent on surplus countries for certain commodities — milk powder is an example. Some time ago, after

some developing countries had become conditioned to depending on imported milk powder, its price was tripled — and the west considered this an appropriate use of the market mechanism. Yet, more recently, when oil-producing countries similarly increased the price of oil, it was decried as unfair and unreasonable. This implies a double standard, and one cannot be surprised if the motives of those involved in various forms of international exchange are sometimes doubted.

4. Such doubts also apply to the "international corporations," despite the suggestion that their investments are benevolent. When we develop an indigenous capability for producing systems which supersede those monopolized by international corporations, they often attempt to prevent such development. Their tactics include the denigration of indigenous expertise and the vilification of our own experts. Their propaganda is sedulously pumped into our elite's information system *via* privileged access to government officials, newspapers, and even our research institutions.

5. Turning to research institutions in particular, how much more attractive it is for our researchers to accept a "fellowship" to go and study the buffalo in, say, California, than to be assigned to study the buffalo in, say, Anand! How much safer for a western country to agree with our "finance" people that a key, foreign-aided research project should be conducted in the aid-giving country's prestigious research institutions rather than in the lesser known institutions, however capable. Thus does the international development lobby tend to look after its own by seeing that east meet west on western grounds, even though this may mitigate against the development which is allegedly being pursued, including research objectives.

6. When such approaches to research (including food and agriculture research) are applied to preconceived Western notions of "industrial development," it is not to be wondered that the research contributes little to appropriate development — nor, indeed, that the development often does not take place at all. When neither the instrument nor the goals are designed to suit the societies on which

they are being imposed, one must not be surprised if the best that can happen is nothing at all.

Conclusion

No doubt, forces against change are often more a matter of mutual back-scratching between the elite involved, than the injurious intent of any one group of nations. No doubt, also, many individuals involved, from all

countries, are highly motivated. Nonetheless, we must face even unappealing facts squarely, in the hope that this may help the many men of good will, who are committed to such work, to see that food and agriculture research will help increasingly to create not only the technological, but also the economic and institutional change, which is needed in all our countries to ensure that both industrial and rural development will serve our social needs.



Quality Standards in Food Processing in Singapore

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Abstract The manufacturing sector contributed 23.5% to Singapore's GDP in 1972 and our food industries formed an important part of this sector. In the same year there were more than 250 establishments employing more than 13,500 workers or about 9% of the work force in the manufacturing sector. Its output in terms of Singapore dollars amounted to more than \$720 million, representing 12% of the total output from the industrial sector. This is our third largest group of industries; the biggest group is petroleum, followed by the electronic and machinery groups. This shows how important our food industries are to Singapore's economy. The output from our food industries has been on the increase for many years and started levelling off in 1971. There is potential for further growth for this industry and there is need to constantly upgrade the quality standards of our food products to keep pace with the improvement of the quality of life in Singapore and in other countries in the region. This is something easier said than done.

Résumé Le secteur de la transformation a contribué pour 23.5% au Produit Intérieur Brut de Singapour en 1972, et les industries alimentaires constituent une partie importante de ce secteur. Au cours de cette même année, plus de 250 entreprises ont employé dans ce secteur plus de 13,500 ouvriers, c'est-à-dire environ 9% de la population active. En dollars de Singapour, leur production a dépassé \$720 millions, soit 12% de la production totale du secteur industriel. Cette activité vient au troisième rang des groupes d'industries: le plus important est celui du pétrole, suivi de l'électronique et de la machinerie. Cela montre combien les industries alimentaires sont importantes pour l'économie de Singapour. La production des industries alimentaires a augmenté pendant de nombreuses années et a commencé à se stabiliser en 1971. Elles ont encore des possibilités de croissance, à condition de relever constamment les normes qualitatives des produits alimentaires, concurrentiellement à l'amélioration des niveaux de vie à Singapour et dans les pays environnants. C'est cependant plus facile à dire qu'à faire.

MAINTAINING and upgrading quality is a continuous process and must be recognized and accepted as such by all concerned: the manufacturers, the workers, and the government (Tables 1 and 2). How to achieve this and remain competitive is always a problem.

Individually, everyone knows what this quality and reliability in food products mean to him. He knows he is being protected from health hazards and is getting value for his hard-earned money. To the manufacturer, better consumer satisfaction means better sales

TABLE 1. Summary of industries in Singapore for year ending 1972.

Industry Group	No. of establish- ments	No. of workers	Output S\$'000	% Output	Value added S\$'000
Food, beverages & tobacco	257	13,552	727,996	11.9	162,297
Petrol & chemical	104	6,851	1,845,457	30.1	355,279
Textile & garments	248	30,539	399,658	6.5	124,391
Sawmills & wood	213	14,338	289,995	4.7	90,025
Paper products & printing	245	10,648	203,723	3.4	104,575
Gum, rubber, plastics, foodwear & leather	191	9,044	167,180	2.7	65,363
Ceramics, glass & nonmetal building materials	44	3,083	102,365	1.7	35,781
Metal & non-metallic numeral products	208	12,678	370,657	6.0	133,700
Machinery, electrical & non-electrical	201	36,831	868,926	14.1	386,523
Transport equipment	98	22,546	553,499	9.0	269,749
Scientific, photographic goods & others	122	10,242	192,770	3.2	54,597
Rubber processing, granite quarries & others	40	4,889	404,485	6.6	38,207
Total:	1,971	175,241	6,126,709	100.0	1,820,484

TABLE 2.

	s\$'000		
	Output	Value added	Direct exports
<i>Year ending 1969</i>			
Food manufacturing	401,248	67,530	146,075
Beverage industries	59,406	32,059	10,956
<i>Year ending 1970</i>			
Food manufacturing	551,361	76,380	185,674
Beverage industries	66,431	34,899	13,127
<i>Year ending 1971</i>			
Food manufacturing	577,621	92,091	183,406
Beverage industries	70,069	35,053	12,408
<i>Year ending 1972</i>			
Food manufacturing	552,016	103,436	158,484
Beverage industries	73,306	33,034	14,579

national economy. This will result in a better life for all which must be the goal of all governments. Although everybody benefits from better standards and better quality products, not many companies or countries, especially the developing ones, have found a satisfactory formula to make their industries produce quality products as an accepted way of life. Generally industries, especially those in developing countries, cannot be expected to change or to improve unless there is a need to do so. Heavy government protection creates a seller's market. In a seller's market, anything can be sold. No quality control movement can succeed under such conditions. In Singapore, our manufacturers have to compete to survive. Possibly it is because of this that we have had some success in our quality drive over the last few years.

and better profits. Workers who have contributed to the companies can expect to get better wages and rewards. Improved national production in terms of quality and reliability enhances trade and hence strengthens the

In this paper, I would like to relate some of our experiences at SISIR. I would stress that there are no rigid rules to follow. Much depends on the various factors we have to contend with in our own countries including: (a) the state of industrialization; (b) the im-

portance of the industries to the national economy; (c) the economic, social, and educational framework of the country; and (d) the individuals involved.

We have taken advantage of other people's experiences and used them as general guidelines from which we develop our infrastructure, organization, policies, programs, and strategies in order to achieve our objectives.

Types of Food Factories in Singapore

The types of food industries in Singapore can be classified into the following broad categories: (a) soft drinks and cordials; (b) alcoholic beverages; (c) edible oils and fats; (d) dairy products (milk, butter, etc.); (e) flour, flour confectionery, and flour products; (f) meat and meat products; (g) fish and fish products; (h) sauces (soya bean, chilli, etc.); (i) sugar; (j) sugar confectionery, chocolate, jams; and (k) fruits, vegetable and agricultural products.

Singapore has an active animal husbandry industry and is self-sufficient in pigs and poultry. All the other raw materials required by the local food industries have to be imported for refining and processing. Most of these raw materials, other than fruits and vegetables, are fairly stable commodities (e.g. flour, sugar, dairy products, soya beans, etc.) available in the world market at competitive prices. Unlike agricultural products like fruits and vegetables which are perishable, the quality of the other raw materials can be controlled and hence the development and maintenance of high quality standards in Singapore's food products is not as difficult as was first envisaged. It is true that processing of fruits and vegetables presents more problems, but this group of factories is relatively small. Because of their size and minimal requirements, they manage to obtain the supplies and the quality they need.

How can we help our food industries to improve (a) their quality, (b) their output, and (c) their exports? What has to be done to maintain, if not to increase, the rate of growth of the food industries, thus giving Singapore

more and better products and savings in imports besides contributing to increases in exports and foreign exchange earnings for the Republic? Before one can answer these questions and find meaningful solutions, one must be able to identify, define the scope and priorities of the problems, and decide what infrastructure, degree of coordination, policies and strategies to be adopted to achieve these objectives.

The Problems

The most commonly met and most widely recognized problems which cause non-conformity to quality standards are technical ones. They include: (a) irregularities of supplies of imported raw materials and variations in their specifications; (b) lack of qualified quality control personnel; (c) lack of know-how; and (d) lack of proper equipment or spare parts.

These technical requirements of personnel, know-how, and equipment are important. Even if these are available, they by themselves are not sufficient to ensure the production and maintenance of quality products in factories. It is true that these facilities are lacking in many companies in developing countries. It is also true that there are some well-equipped laboratories with good buildings and technically qualified personnel both in government and in the private sector which are not very effective. Why? I would like to suggest that commitment and involvement of the individuals concerned is missing.

In a quality control program, we need commitment by government, manufacturers, and workers at the same time. Unless the three parties can work together, the national program can never succeed. Without the workers' cooperation, quality products cannot be produced. Without management's support no quality control program can be started in any company. The government's role is to formulate proper policies and to ensure that everyone plays by the accepted rules of the game. The consumer needs to be protected from those who want to make a fast profit at their expense. Those "fly-by-night" operators could not be allowed to damage the good name of

Singapore as a manufacturing nation, thereby jeopardizing the long-term interest of developing Singapore into an industrialized nation. How does an organization coordinate the activities of these various groups with conflicting interests?

Infrastructure

The Singapore government recognizes the importance and accepts the need to improve national production in terms of quality and reliability. To regulate and to assist the food industries, it has set up the following organizations with appropriate functions: (see below)

The responsibilities of the various departments and institutions are quite distinct. However, their activities toward establishment of quality standards in food are well coordinated. There is good communication and understanding between the staff of the various government agencies and the manufacturing sector. Staff from all these organizations and those from the industries are actively involved in the preparation of standards under the Standards Council of SISIR.

Types of Standards

In food there are broadly two types of standards: (1) the *mandatory* type where consumer's health and safety are involved. These standards are usually laid down in the Sale of Food Acts of most countries. These acts also include labelling requirements to prevent consumers from being cheated; and (2) the *voluntary* type. These types are usually difficult to define. Although standards are available for the most common and more basic types of food such as flour, sugar, condensed milk, etc., specifications are much more difficult to produce for the others because of the subjectiveness of individual and cultural tastes. Nevertheless, company or contractual specifications are usually available for such products.

Obviously there can be no compromise insofar as meeting statutory requirements is concerned. How closely food industries in a particular country observe these standards depends on how effective the law enforcement agencies are.

On the other hand, it is not possible to compel industries to adopt voluntary standards by

Organizations

- (a) Economic Development Board (EDB)
- (b) SISIR — The Singapore Institute of Standards and Industrial Research
- (c) Commissioner of Public Health, Inspectorate and Licensing Division Ministry of the Environment
- (d) Department of Chemistry, Ministry of Science and Technology
- (e) Department of Primary Production, Ministry of National Development
- (f) Department of Chemical Technology, Singapore Polytechnic
- (g) Department of Chemistry, Department of Pharmacy, University of Singapore

Functions and Responsibilities (related to food industries)

To implement government policies related to industries, including food industries

- (i) Drafting of standards for food
- (ii) To promote growth of quality control circles and movements in Singapore
- (iii) To assist food industries in upgrading quality standards

- (i) Issue licenses to food industries
- (ii) Enforcement of Sale of Food Act, including imported foodstuffs

- (i) Assist Ministry of the Environment in enforcement of Sale of Food Act by offering testing and related services.

- (i) Assist the development of animal husbandry (pig and poultry industry)
- (ii) Runs the abattoir and ensure quality standards in meat and fish products and export

Training of technicians for food industries

Training of chemists and food technologists for Government and industries

law. Incentives and sometimes disincentives have to be used.

In order to get our industries to do what is good for them, we have adopted a "carrot and stick" approach to encourage and persuade our food industries to adopt strict quality control in the manufacture of their products.

SISIR's Development and Its Program on Quality

When Singapore first embarked on industrialization, efforts were mainly devoted to the development of the necessary infrastructure and essential facilities. Fiscal policy as a whole was directed toward the creation of a highly attractive investment climate for manufacturing industries.

The broadening of the industrial base and growing diversification of manufacturing activities led to increased demands for specialized technical services. To meet this demand, the Economic Development Board in 1964 established the following consultant units: the Light Industries Services, the Productivity and Training Unit, the Standards Unit and the Industrial Research Unit.

The Light Industries Services had a food industries section which gave advice to food industries to assist them to improve the quality of food products manufactured. The service grew into a food extension and demonstration service and its activities centred mainly on provision of advisory services on food processing techniques and the use of better equipment and machinery. Some R & D work was carried out on canned meat products, chilli sauce, tropical fruit concentrates, vegetables, soya sauce, etc. Quality standards and quality control work for the food industry did not receive much attention and support in the late 1950s and early 1960s. This was due to a large extent to early teething problems of industrialization. Protection, shortage of skilled labour and absence of competition did not help to encourage quality control and consciousness in the industries.

Recognition of the need to build up permanent standards and industrial organizations as Singapore proceeded to the next stage of its

industrialization program, which would involve quality control, standardization, and product development, led to the formation of SISIR in 1965.

Under SISIR, standardization and quality control assumed greater prominence and through deliberate efforts and long-term programs, quality consciousness was inculcated into the nation's manufacturers, workers and consumers.

The SISIR Program

A national quality improvement program can be initiated either through legislation and regulatory measures or on a voluntary basis. SISIR decided against using legislative measures. Instead, it designed a program based on education and motivation to persuade manufacturers to subscribe to the quality concept. This approach to quality improvement — looking at a quality control program as an investment proposition for the long-term survival and prosperity of a company — seemed more likely to succeed for a country, which prior to industrialization, depended wholly on its entrepot trade and the business acumen of its people.

Today, 5 years after the establishment of SISIR, over 300 different brands and products manufactured in Singapore bear the SISIR Quality Mark, and this number is rapidly increasing. Training and educational courses have been conducted for more than 1000 workers from industry, and the institute has expanded more than three-fold in 5 years, and it is still growing.

The following is an outline of SISIR's program on quality control and standardization in Singapore, with particular reference to the food industries.

Standardization

As the Certification Scheme gained momentum, and more industries desired to participate, new standards had to be drawn up. Initially, we pursued a policy of adopting international standards for industrial products, but as local conditions and environments were

different, Singapore Standards had to be introduced.

The Certification Scheme would be of little value unless backed by standards which can be accepted on a global basis. Care had to be taken to ensure that Singapore Standards were not too low by international standards nor too high as to make compliance impossible. This task of striking the correct balance in standards promulgation fell on the Standards Council of Singapore, a body set up in 1969 to advise SISIR on standardization policies and goals. The Standards Council comprised representatives of the manufacturers, trading organizations, consumers, professional bodies, the universities, and government. During any one year, more than 300 volunteers are engaged in the preparation of Singapore Standards.

Fifteen to twenty per cent of standards published to date are on food and food products. As it is the Institute's policy to bring more of the daily necessities and basic commodities under the Certification Scheme, an increase in food products standardization and Codes of Practice can be expected over the next few years.

Technical Information

To keep the manufacturing industry informed of new industrial developments, manufacturing techniques and quality control developments, SISIR established an "Industrial Technical Information Service" two years ago. The service covers 26 different industrial areas of which food and beverages, and quality control are but two of them.

ITIS operates a Question and Answer Service and a Current Awareness Service. The Current Awareness Service is only confined to subscribing members. Out of the present 156 members, 20% are from the food industries.

Quality Certification

The need to upgrade the quality of Made-in-Singapore products to enable greater export participation in international markets was the main reason why SISIR introduced a Certification Scheme for Singapore industries in 1969.

Basically, the Scheme permits a manufacturer whose product, if manufactured under an efficient quality control system and regularly tested and found to conform to acceptable international standards, to be awarded a licence to use the SISIR mark on the product. The scheme provides a third party guarantee as licence to use the mark is only awarded if a product, after a series of intensive tests and inspections by SISIR, shows consistent conformance to the respective standard. Today some 150 companies with over 300 different brands and products are covered by the SISIR Certification Scheme. The food industry, traditionally the most conservative of industries, accounts for more than 60 brands and products. Many more factories and products are under testing and consideration for the award of SISIR's licences to use its mark.

Consultant and Retainer Scheme

SISIR offers consultancy services, especially to food industries, on a retainer basis. Under this Scheme, SISIR officers visit the factories regularly to assist the food industries solve their problems. A mobile training unit donated by the Canada Plus One project is extensively used for this purpose. This mobile laboratory is stationed for about 2 weeks in each factory during which time SISIR officers manning the laboratory give lectures, talks and demonstration on food hygiene and conduct on-site microbiological tests and examinations to impress on workers the danger of bacteria contamination, the importance of clean attire and the need to wash their hands etc.

This retainer scheme was started about 1½ years ago. Depending on the size of the factories, they are charged S\$100–150 per month. At present, there are some 40 small and medium size food establishments on this Scheme. SISIR hopes to be able to assist them to qualify for the Good Housekeeping Scheme and ultimately award the SISIR Licence or quality certification on specific products.

National Quality and Reliability Campaign

To project the proper image of the quality and reliability of Made-in-Singapore goods

and also the skills and dependability of our workers, SISIR in conjunction with the National Trades Union Congress — representing organized labour in Singapore — and the Singapore Manufacturers' Association — representing the manufacturers — organized a year-long nation-wide "Prosperity through Quality and Reliability (PQR) Campaign" in 1973 with the active participation of the Minister for Finance as the Patron.

The Campaign involved more than 200 companies and some 70,000 workers — representing 50% of the work force in the manufacturing sector — and included incentive awards and recognition for outstanding workers, group activities aimed at improving the work environment, elimination of defective products, prevention of errors, and improvement of yield in industry. The Campaign was also directed at the general public through their participation in such competitions as the PQR Stamp Selection Contest. A national Science & Industries Quiz was organized for the school children to make them aware of the importance of quality in industrial production. Seminars, talks and training courses were conducted for management and workers in industry.

Although the Campaign was not directed specifically at the food industries, nonetheless the Campaign sparked off sufficient interest from them and led to SISIR initiating a special program for food industries alone. This is the "Good Housekeeping" Scheme which is discussed below.

Good Housekeeping Scheme

In order to coordinate the efforts of Singapore's food manufacturers in the maintenance of high sanitary standards in manufacturing practice, SISIR is embarking on a scheme where participants will subscribe to a Good Housekeeping Code.

The Code lays down health standards for the industry, conditions for food handling and hygiene practices for employees of food factories. An inspection program backed by chemical and microbiological testing will be undertaken by SISIR as part of the scheme. The

mobile food laboratory will be used to provide on-the-spot laboratory testing facilities and also as a teaching laboratory for the factory workers. The scheme was launched early this year and operates with full cooperation from the Ministry of the Environment, the government agency responsible for food licensing in Singapore. It is expected that in the course of time only factories with the Good Housekeeping Certificate will be allowed to operate and to export processed food without export inspection.

Export Inspection

At the moment, SISIR carries out export inspection of products as and when requested by the importers or the manufacturers. So far, these requests have emanated mainly from the food industries.

In cases where Singapore's good name as a manufacturing nation may be affected, the Government would not hesitate to make export inspection of certain types of goods compulsory, especially those which involve the health and safety of the consumers. Provision for this already exists in the SISIR Bill.

Government Support

In 1974-75 the Singapore government expects to spend about S\$4 million in the running of SISIR alone. This does not include the expenditure required to run the other establishments mentioned earlier. This reflects the importance the government attaches to the development of our food and other industries in Singapore.

Conclusion

The importance of quality standards in food processing cannot be over-emphasized. The need to be competitive, the lack of protection coupled with government's active encouragement and support for better quality and technology in all industries have made many of Singapore's industries, including the food processing industries, accept as a fact of life that their survival and prosperity depend entirely on their ability to produce quality

products at competitive prices. Given continued cooperation and understanding by all concerned — the workers, the manufacturers and the staff of government agencies — the food processing industries should continue to do well in Singapore in the years to come.

