THAI-USOM COOPERATION
IN THE PROMOTION OF CORN
PRODUCTION IN THAILAND

by

Charles A. Bredtungbach
USOM AGRONOMY ADVISOR

BANGKOK, THAILAND
INTRODUCTION

In the present report the writer has attempted to illustrate the cooperative role USOM has played in helping to promote Thailand's corn industry. In many cases that attempt may give the mistaken impression that USOM achieved this progress alone. Actually, such is not the case. The effort that has promoted this industry is the direct result of a very close cooperation between USOM and the Government of Thailand.

It has, in fact, been difficult to separate the efforts and contributions of USOM and those of the Thai Government. During many years of its operation USOM did not attempt to distinguish its development programs from those of the host country. The cooperating parties, to a large measure, acted as one. As a result, the part each government played in corn development cannot be defined precisely.
PART I, THE DEVELOPMENT OF THAILAND'S CORN INDUSTRY

A. The Importance of Corn to Thailand's Economy

Among the developing nations, Thailand is cited as one which has made outstanding economic progress. The Kingdom's development is noteworthy on two accounts. First, it has moved at a rapidly accelerating pace since 1950. Second, this progress has been achieved quite largely through increased agricultural production. In contrast, the European community of nations, Japan, and other countries emerging from instability after World War II, depended on industry for their recovery.

The story of Thailand's economic progress is directly related to that of its crop diversification, a program in which the AID program has played a major role. It is more than a coincidence that U. S. technical assistance to Thailand began in 1950 and that one of its strongest programs has been that of crop development.

Before 1950, the Kingdom depended heavily on rice for her foreign exchange earnings. That year 34,625,000 rai \(^1\) were planted to the crop. The rice harvest equalled 6,782,000 tons and its value was estimated at \(^2\) $5,190,600,000. Total rice and rice product exports equalled 1,419,090 tons and earned $1,674,285,000 in foreign exchange.

In the same year, 1950, only 218,000 rai of corn were planted. Production equalled 26,900 tons and the value of the crop was estimated at $29,100,000. Of this, 12,630 tons were exported and earned $10,479,000 in foreign exchange.

\(^1\) 1 rai = .395 acre
\(^2\) 1 baht = $.05
Ten years later, in 1960, 37,107,000 rai of rice were planted and 7,789,000 tons of rice were harvested having an estimated value of ¥6,628,100,000. Total rice and rice product exports equalled 1,213,040 tons and earned ¥2,596,241,000 in foreign exchange.

In contrast to rice, by 1960 developments in corn were remarkable. 1,785,000 rai of corn were planted, 543,900 tons of grain were harvested and the value of the crop was ¥549,300,000. A total of 514,745 tons of corn were exported, earning the nation ¥550,734,000 in foreign exchange. In a ten-year period the area planted to corn increased more than 800 per cent. Production increased more than twenty times over that of 1950, and the foreign exchange earned by corn was over 21 per cent of that earned by rice in the same year.

Over the same ten years the area in rice production increased only 2,482,000 rai, a relatively small expansion. Most areas suited for paddy production had been under cultivation for many years already and new areas of inundated land for expansion were, practically speaking, no longer available. Although production in 1960 exceeded that in 1950 by 1,007,000 tons, total exports were actually down by 206,050 tons. This reflects a general increase in national prosperity which enabled people to consume more rice, and a population increase estimated at 3½ per year. The increased value of exported rice in 1960 as compared to 1950 was ¥921,956,000 a gain which resulted largely from the higher price of Thai rice on the international market.

\[\text{In 1960 the value of the corn crop was ¥549,300,000 while the nation earned ¥550,734,000 in foreign exchange. The difference resulted from a hold-over of part of the 1959 crop, the sale of which was reported under 1960 exports.}\]
Recently released figures show that the 1962 corn crop reached 684,827 metric tons. The value of the crop was \$787,050,000. A total of 612,837 \textsuperscript{1} tons were exported, earning \$651,568,300. By 1962 Thailand was the world's fourth exporter of corn, ranking after the U. S., Argentina, and South Africa. This demonstrates the importance corn has assumed in the national economy.

\textsuperscript{1} Due to difficulty in agreement on fixing an equitable sale price with Japan, exports to that nation began late in 1962 and then continued well into 1963. The figure \$651,568,300 is the earnings from the 1962 commitment though sales extended beyond the calendar year.

\textsuperscript{2} In 1962 an additional \$13,613,555 was also earned by the export of 11,723 tons of corn meal.

Note:

Statistics in this section were taken from "AGRICULTURAL Statistics of Thailand, 1960 - A bulletin printed by the Agricultural Statistics Section, Division of Agricultural Economics, Office of the Under-Secretary of State, Ministry of Agriculture, Bangkok, Thailand.

1962 figures are based on yet unpublished information recorded by the port authority of Bangkok.
B. USOM's Cooperative Role in Crop Diversification

By tradition the Thai people have been rice farmers. Their culture for centuries has depended on rice. Until recently there was good reason to maintain that pattern. The uplands were largely jungles and without heavy equipment they were difficult to clear. Malaria was a serious problem and communication was almost non-existent because of the lack of roads.

USOM-Thai Cooperative efforts have been influential in changing the situation. By 1950, when the program began, it was already clear that rice culture had been extended almost as far as was advisable. Such early agronomy advisors as Dr. H. H. Love recognized that an improved rice culture would not support the national economy by itself. While he worked to develop the superior rice varieties Thailand is using today, he recommended that the Agriculture Department be strengthened and made independent of rice. A separate Rice Department was formed and Agriculture was encouraged to intensify its research on upland crop production.

Among its first efforts the Crop Development Project introduced and tested large numbers of rice as well as upland crops. Dr. Love and Mr. Howard Ream were early U. S. instigators in this program. Among the Thai counterparts were Dr. Sala Dasananda and Dr. Krui Punyasingha. Besides corn, many varieties of kenaf, cassava, castorbean, edible legumes, fruit crops and vegetable seeds have continued to be introduced and tested under the program started then. The development of means by which such crops can best be produced and multiplied under local conditions has been the second phase of this program. Today evidence of the success of the work is shown by the rapid opening of upland areas for the production of new crops. A whole series of such crops are now grown on permanent farms which employ the improved farming practices worked out under the Crop Development
Project. In some cases the program has entered a third stage, i.e. specific breeding programs. An example of this is work on corn to develop varieties which fit specific needs. That work is reported under Part II of this paper.

The success of the crop development program is illustrated in the following table which shows the area cultivated, the production, and the export value of four principal upland crops: corn, kenaf, cassava and castorbean from 1950 to 1960.
<table>
<thead>
<tr>
<th>Year</th>
<th>Corn (1,000 rai)</th>
<th>Kenaf (1,000 tons)</th>
<th>Cassava (1,000 tons)</th>
<th>Castorbean (1,000 tons)</th>
<th>Production Value of Exports (1,000 Baht)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Kenaf</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cassava</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Castorbean</td>
</tr>
<tr>
<td>1950</td>
<td>218</td>
<td>31</td>
<td>25</td>
<td>27</td>
<td>26.9</td>
</tr>
<tr>
<td>1951</td>
<td>259</td>
<td>88</td>
<td>25</td>
<td>82</td>
<td>41.7</td>
</tr>
<tr>
<td>1952</td>
<td>281</td>
<td>67</td>
<td>86</td>
<td>79</td>
<td>44.8</td>
</tr>
<tr>
<td>1953</td>
<td>293</td>
<td>60</td>
<td>94</td>
<td>65</td>
<td>51.1</td>
</tr>
<tr>
<td>1954</td>
<td>331</td>
<td>37</td>
<td>94</td>
<td>94</td>
<td>62.3</td>
</tr>
<tr>
<td>1955</td>
<td>347</td>
<td>53</td>
<td>86</td>
<td>91</td>
<td>67.5</td>
</tr>
<tr>
<td>1956</td>
<td>514</td>
<td>109</td>
<td>55</td>
<td>118</td>
<td>114.8</td>
</tr>
<tr>
<td>1957</td>
<td>606</td>
<td>78</td>
<td>240</td>
<td>166</td>
<td>136.8</td>
</tr>
<tr>
<td>1958</td>
<td>792</td>
<td>127</td>
<td>276</td>
<td>144</td>
<td>186.3</td>
</tr>
<tr>
<td>1959</td>
<td>1,249</td>
<td>278</td>
<td>391</td>
<td>176</td>
<td>317.2</td>
</tr>
<tr>
<td>1960</td>
<td>1,785</td>
<td>877</td>
<td>447</td>
<td>197</td>
<td>543.9</td>
</tr>
</tbody>
</table>

Agricultural Statistics of Thailand, Bulletin by Agricultural Statistics Section Division of Agricultural Economics, Office of the Under-Secretary of State, Ministry of Agriculture, Bangkok, Thailand.
The samples cited are important because they represent export crops which earn foreign exchange upon which the growth of the national economy depends. Equally important, though not cited, is increased production of the edible legumes such as peanuts, soybeans and mungbeans of the vegetable crops and of the local fruits. In the latter cases, increased production has largely gone into domestic consumption.

What has been achieved is the result of several joint Thai programs. The Crop Development Project could not have done the job alone.

Beginning in 1950, the Malaria Control Program freed thousands of rai of upland areas of malaria and made them habitable for cultivation. USOM-financed roads such as the Friendship Highway made communication possible in areas that had been inaccessible. Along such roads, it became possible to transport the new crops back to the consuming markets. USOM assisted land settlement cooperatives and with USAID-procured bulldozers, the jungles were cleared for these settlements. USOM assistance helped the developing rural areas with Community Development projects, with Agricultural Extension Education, and with Credit and Marketing Coops. USOM expenditures helped bolster the nation and stimulate its economy.
C. The Early History of Corn in Thailand

The first introductions of corn into Southeast Asia date back to a period shortly after the European colonization of the Americas. Corn was brought to Europe on Columbus' second voyage from the New World. Soon thereafter Portuguese merchant ships introduced the crop to Africa. By the middle of the 16th century, the Portuguese are known to have taken corn to China. Probably it also arrived in Thailand about this time as the Portuguese ships that traded with China also frequented ports in Thailand in the 16th century. In any case, corn was being grown at Ayuthaya by the middle of the Ayuthya period 1350-1767. The crop, however, appears to have been grown mostly as an oddity until relatively recent times.\footnote{This is not true of the Hill Tribes of Northern Thailand who appear to have been growing and utilizing a rustic type of corn as part of their diet over a long period. The first Christian missionaries to work among them in Burma noted that these people were growing corn in the middle of the 19th century. At the higher altitudes at which the Hill Tribes live the conditions are poor for the production of rice, though it is the staple diet. Corn may have caught on because it yielded a larger crop and could be grown with very little care.}

After World War I, sporadic interest developed in the production of corn among certain individuals who had the opportunity to observe it in the United States. Such a person was Prince Sidhiporn Kridakorn who introduced two varieties of dent corn in 1932, while Director General of the Department of Agriculture. These were multiplied and grown at the government farms
for livestock feed. From then on, production gradually expanded. As far as is known, subsequent introductions were of U. S. origin and were apparently not well adapted to local conditions. They were poor in yield and quality.
D. The Introduction of "Guatemala" Corn

One of the early activities of the Thai-USOM Crop Development Project was the introduction and observation of large numbers of crop varieties. Among these corn was one of the most important. In 1950 and 1951, under Dr. Love's direction, the program introduced a collection of corn varieties from the U.S. and a second collection from Indonesia, where the Dutch had been active in corn research.

In 1951 Mr. Howard Ream assisted in the plant introduction work together with Mr. Somchai Dhammoonragsa. From their observations, one variety among the Indonesian collection especially impressed them. The variety responded better to local conditions than did the American material. It yielded well and the grain was a flint type with a beautiful golden yellow color. The variety was called "Tiquisate Golden Flint". It had in fact been introduced to Indonesia from Guatemala only a short time previously.\(^1\) Mr. Ream selected this variety which he called "Guatemala" corn for propagation.

On Mr. Ream's advice USOM obtained 100 lbs. of "Guatemala" corn seed directly from its country of origin. This was multiplied at the Bangkhen and Tha Pra Agriculture Experiment Stations during the 1952 growing season and distributed to selected farmers for further multiplication in 1953. The variety proved so successful that it rapidly became Thailand's only corn for commercial production. It is estimated that "Guatemala" corn now accounts for more than 95% of the corn exports.

\(^1\) "Tiquisate Golden Flint" was produced by the Iowa State Tropical Research Center in Antigua, Guatemala. It was developed as a varietal cross between a Cuban flint corn and a Guatemalan dent variety. It was taken to Indonesia in 1949 by the director of the center, Dr. Melhuse who served at the time as a consultant on a six month assignment in Indonesia.
The program for introducing and multiplying "Guatemala" corn achieved outstanding success. In 1962, ten years after the original propagation, corn production had expanded from 281,000 rai to well over two million rai and the value of the crop had increased from about 46 million baht to over 787,000,000.
E. The Broader Aspects of Corn Production

One occasionally hears the opinion that the construction of the Friendship Highway, also USOM supported, was responsible for the success of corn production in Thailand. Although it is true that large areas adjacent to the highway have become profitable corn producing areas, due in part to the convenient market access provided by the new road and to newly developing foreign markets, it is also true that without the work of the agronomists who sought out, tested, and established a well adapted variety, and who had the seed multiplied, distributed and grown, the crop could not have prospered in the area. Moreover, only about one-third of Thailand's corn is produced in the vicinity of the highway. It is, however, of interest to note that the 1960 and 1961 export earnings of the Guatemalan corn grown in the vicinity of the heralded Friendship Highway could of themselves pay for the total cost of its construction. Such observation helps to bring into proper perspective the relative importance of activities such as those of Crop Development, which are comparatively insignificant in cost and seldom make dazzling headlines, yet which contribute importantly to the development of Thailand's economy. This is amply supported by another simple comparison: the total cost of the Agronomic Development Project in baht and dollars for the ten-year period 1952-1962 has been about $7 million,1 whereas the total export earnings of "Guatemala" corn alone have been approximately $130 million during the same period.

1 It is estimated that not more than 10% of this sum was used for corn research. For a detailed break-down of how project funds were spent see PART II, Section J. "The U.S. Contribution to the Crop Development Project".
The Effect of Management Practices in Increasing Corn Production

Since 1951 the Crop Development Project has supported activities in the fields of Agronomy, Soil Fertility and Crop Defense. Soon after the introduction of "Guatemala" corn it became apparent that its yield depends heavily on the management practices employed in growing it. Specific requirements need to be provided if the variety is to approach the yield of which it is capable.

The requirements of the crop were systematically studied and the results of this research have gradually been passed on to the growers through farm demonstrations and extension education. The success of this research is borne out by continued national average increases in corn yield. In 1950 the average yield of the corn crop was 127 kg. per rai. By 1955 it had reached 196 kg. per rai. From then to the present the national average has continued to increase ever more rapidly as shown by the following table. By 1961 the national average reached 321 kg. per rai, but by then it was apparent that, because of soil depletion, some areas were already in danger of rapid decreases in production. The need of chemical fertilizers and of land conservation practices had become evident. This problem is discussed in a later section.
Table 2.

AVERAGE CORN PRODUCTION INCREASES (1950-1961)

<table>
<thead>
<tr>
<th>Year</th>
<th>Av. Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>127 kg/rai</td>
</tr>
<tr>
<td>1951</td>
<td>163 &quot;</td>
</tr>
<tr>
<td>1952</td>
<td>165 &quot;</td>
</tr>
<tr>
<td>1953</td>
<td>173 &quot;</td>
</tr>
<tr>
<td>1954</td>
<td>191 &quot;</td>
</tr>
<tr>
<td>1955</td>
<td>196 &quot;</td>
</tr>
<tr>
<td>1956</td>
<td>225 &quot;</td>
</tr>
<tr>
<td>1957</td>
<td>229 &quot;</td>
</tr>
<tr>
<td>1958</td>
<td>238 &quot;</td>
</tr>
<tr>
<td>1959</td>
<td>256 &quot;</td>
</tr>
<tr>
<td>1960</td>
<td>306 &quot;</td>
</tr>
<tr>
<td>1961</td>
<td>321 &quot;</td>
</tr>
</tbody>
</table>

1) Time of Seeding

Among the early research on "Guatemala" corn was a study on its response to sunlight. Time of seeding was found to be closely related to production. American technical advisors and Thai counterparts worked together to study the problem. They found that in each area, highest yields were obtained when "Guatemala" corn was planted as early as possible after the rains set in. Subsequent trials under irrigated conditions showed that the variety's ability to yield was proportionate to the number of sunlight hours it received. Thus rain was the limiting factor in determining how early to plant the crop in any particular area. The rain records over many years were studied and from them recommended seeding dates were worked out.
for the entire Kingdom. They correspond in each area to the earliest date that the monsoon normally falls in a continuous pattern. In the area adjacent to the Friendship Highway, the rainy season is somewhat longer than in Saraburi and Lopburi, Thailand's two other major corn production areas. This allows the production of two crops of corn in some seasons. The practice is not recommended because the first crop must be planted in April or May, at least a month before the rains normally fall on a continuous basis. The first crop frequently fails or, because of insufficient rain, it develops poorly. The second crop likewise yields less than a planting at the recommended seeding date because it cannot be planted until August or September, two months after the recommended seeding dates. USOM and the Ministry of Agriculture jointly recommend one crop of corn followed by a grain legume in the area.

2) Method of Seeding

It was found that drilling the seed in rows, a method of planting generally practised in the U.S., was not best when using the "Guatemala" variety. Unlike many American hybrids, it never tillers and generally produces only one ear per stalk. This may account for the fact that best yields are achieved when the variety is grown in hills. Successive trials have revealed that a planting distance of 1 meter between rows and fifty cms. between the hills in a row produce the highest yields.

Two plants per hill have been found to be the best number on old soils. This is equivalent to 6,400 plants per rai. On new land or on soils where adequate rates of chemical fertilizer are applied 3 plants per hill, a population rate of 9,600 plants per rai, have given the highest yields.
3) Seedbed and Cultivation Practices

The USOM agronomy advisors have continuously recommended that the seedbed be carefully prepared before planting corn. They have recognized the need of good cultivation to control competitive weeds. The importance of good farm management practices was difficult to explain to the new generation of corn farmers. Many of them had been accustomed to growing rice, a crop in which the fields are left unattended after the seed has been planted until the rice is harvested.

Controlled trials were run in 1955 and 1956 by the USOM Agronomy Advisors Messrs. Reece Dampf and Gordon Middleton to compare the yields obtained when "Guatemala" corn was planted on poorly prepared land without cultivation and when the crop was grown with adequate land management practices. They found that the yield was proportionate to the care given it. Middleton was responsible for influencing some of the farmers in the Pakchong Area who first imported tractors. Since then the success of those farmers and the boom in the corn market has encouraged the importation of an ever increasing amount of farm machinery. As a consequence, seedbed preparation and cultivation for the control of weeds has improved each year.

4) Corn Fertilization

The Crop Development Project has placed considerable emphasis on corn fertilization and the use of chemical fertilizers in the production of corn. Numerous comparative yield trials have been run in various parts of Thailand and generally they have demonstrated a good response to fertilizer use. However, the use of chemical fertilizers on corn has not expanded as fast as had been hoped. The reasons for this are various. The cost of fertilizer is relatively expensive. Adding to the expense is the fact that
transportation costs are high. Usually the farmer lives on credit until he can sell his produce. Interest rates are high. The use of chemical fertilizers has thus not always been compensatory, a fact which has led to the widespread belief that fertilization is not necessary. Besides, there is confusion on the part of individual farmers as to what fertilizer ratios, grades and rates should be employed on their particular farms.

Considerable progress has been made in lessening the confusion. As a result, the use of fertilizers in corn production is now helping to increase the national production average.

The first step in the fertilizer research program was to find a suitable ratio of Nitrogen, Phosphorus and Potash. A 2N:2P₂O₅:1K₂O ratio gave the best results for most corn producing areas of Thailand. As the soils analyses of the areas show that the natural supply of Nitrogen and Phosphorus is moderate while that of Potash is high, the 2:2:1 ratio found best in yield trials is as expected.

Next, different grades of fertilizers compiled in a 2:2:1 ratio were compared to determine which formula gave highest response at least cost. A 12:12:6 formula was calculated to be the most economical. This is equivalent to 12 kgs. of available N, 12 kgs. available P₂O₅ and 6 kgs. available K₂O for each 100 kgs. of the formula used. The sources of fertilizer generally employed are ammonium sulphate, double superphosphate and potassium chloride.

Finally, so as to make further headway in dispelling the confusion, a general application rate of 12-12-6 fertilizer grade was sought. In most cases this has turned out to be 50 kgs. per rai or the equivalent of 6 kgs. N, 6 kgs. P₂O₅ and 3 kgs. K₂O per rai for soils of average fertility. Of course,
this is too low an application rate for depleted or poor soils and in each case it would be best to have a soils analysis before making an individual recommendation.

5) The Use of Green Manures

A program was undertaken to test the effect of a late crop of green manure at the end of the previous season on increasing the corn crop the following year. Twelve green manures were grown and turned under, both alone and with different fertilizer treatments. It was found that of the twelve green manure species, Crotalaria juncea gave the best results in increasing corn production.

When chemical fertilizers were used in conjunction with the Crotalaria crop, the most effective one was a single application of double superphosphate at a rate equivalent to 6 kilos of available P$_2$O$_5$ per rai. This should be applied at the time the Crotalaria is seeded.
G. The Crop Demonstration Program

By 1959 "Guatemala" corn was well disseminated throughout the Kingdom. It was available to anyone who wished to use it for seed; in fact it was already difficult to buy the previously established varieties. The basic agronomic requirements for good production already had been established for the variety, though the use of these practices was still limited.

Many upland farmers continued to plant corn on the basis of a primitive shifting agriculture. The brush or forest was slashed down and the larger trunks burned. The crop was seeded in patches, worked between the remaining roots. Such a system allows for the production of two or at most three corn crops. Then yields decline and the farmer has to move to a new area allowing the old patch to revert back to brush.

The available research findings were slow in being extended. The Agronomy Advisor in 1959, Dr. Jameson Bell, believed that a crash demonstration program was the best way to get Thailand's rice-oriented upland farmers to employ the new practices tested under upland farming conditions. The province of Udorn was chosen for this program and with the assistance of the Soil Chemistry Division of the Department of Agriculture, the resources of the Crop Development Project were placed behind it. Mr. Jin Rakkarndeewho was then governor of Udorn, also supported the program enthusiastically and backed the demonstrations with the assistance of the strong community development organization which he had developed. In 1959 every village in Udorn was provided with demonstrations on improved methods of growing upland crops. There were demonstrations in 916 villages. There were 475 sugar cane demonstrations, 644 peanut demonstrations, 1,832 plots demonstrating the use of green manure crops and 721 demonstrations on the newest methods of corn production.
The program has been criticized for its over-saturation of efforts. Many officials within the Department of Agriculture felt that the same results could have been achieved with fewer demonstrations and a stronger program of farmer extension education. They considered that the program provided an excessive use of project funds for a single province and believed that this should not have been justified since it meant other crop development activities of more general application had to be restricted. Nevertheless, in retrospect the 1959 program helped to produce very positive results. Through the undertaking the value of farm demonstrations was made clearly evident as a method for getting new upland practices accepted. The demonstration techniques developed then have continued to prove effective in the cooperative USOM-Department of Agriculture efforts to expand the establishment of upland farming on a permanent basis. In fact, Dr. Bell's initiative and the techniques he employed are often given credit for first having gained large scale acceptance of what were then newly tested farm practices. Since 1959 similar farm demonstrations have been employed on a more moderate scale throughout most of the Kingdom's upland farming areas. They continue to be an important tool of the Extension Service.
PART II. RESOLVING TECHNICAL PROBLEMS OF CORN PRODUCTION IN THAILAND

A. The Problems Related to National Corn Production

As corn production continued to rise in the late 1950s the nation became dependent on the foreign exchange the crop earned. Nevertheless, there were already warnings that the crop's long term expansion was threatened. These are discussed below.

1) Thailand's Restricted Market

One of the problems Thailand's corn trade faces has been its unbalanced dependence on a single market. About 80% of Thailand's corn goes to Japan. Her other markets are Hong Kong, Singapore and Malaya (14%) and the United Kingdom (6%). For this reason the Japanese have held a strong bargaining position and they have used it. They have justly complained about the high moisture content in Thai corn. They have caused concern in influential government circles by a persistent claim that the desired golden yellow color of "Guatemala" corn is degenerating and losing its intensity.  

\[1\]

\[1\] Guatemala corn was in fact developed as a cross between a golden flint and a canary colored dent. This intervarietal origin is responsible for its good production. At the same time it results in a certain percentage of segregation each generation to the lighter colored parent type. There is no evidence that the rate of the segregation is increasing. A poor selection of ears for seed, i.e. a selection for size with a disregard for color, can increase the amount of light colored grain in the following generation. This problem is being met by a seed certification program discussed later.
2) **Intensive Cultivation without Fertilizer Usage**

By 1960 it had become apparent that the entire belt along the Friendship Highway where corn production had made its initial advances was threatened by soil depletion. After two or three cultivations without chemical fertilizers the production on many farms tapered off seriously. However, this is the area where double corn cropping has been extensively practiced. The use of proper seeding dates, advised seeding rates and good soil tillage practices did assist in increasing production, but they could not prevent production decreases when soil fertility became depleted. Also serious erosion is developing due to the clearing of forests on land too steep for row cropping. In short, over-intensive cultivation is already a problem.

3) **New Land for Further Expansion Is Limited**

In Thailand where upland farming has had a short history the problem of shifting agriculture was not recognized at first. With the increase in upland farming, new lands available for cultivation have been reduced. Consequently, in recent years an effort has been made to preserve existing forests for the nation. This means future increases in national corn production will have to be achieved largely through improved farm yields per unit area. Soil and water conservation practices will have to be taught and applied. Chemical fertilization will be required on an expanded scale and superior varieties must be developed.

4) **A Need to Obtain Improved Corn Varieties**

The realization that "Guatemala" corn was not a fixed type and the knowledge that its yield potential is below that of American Hybrids, has caused concern.
In 1957 Mr. Somchai Dhamnonragsa, after a year's training under the U.S. participant program, returned to Thailand with a large number of U.S. inbred lines. He began to make hybrids in Thailand. His hybrids yielded better than Guatemala corn, but they were dent, a type of corn unacceptable to the Japanese market. Also, under the tropical conditions of Thailand most of the U.S. inbred lines were too weak to be maintained.

In 1958 Oregon University, under USOM contract to assist Kasetsart University, initiated a second series of hybrid investigations. Dr. F.E. Fore, the Oregon corn-breeder, introduced a collection of hybrid corn varieties from the U.S. and the Philippines. A number of Dixie hybrids and one Philippine hybrid showed good yield potential, but this hybrid program was also faced with serious hurdles for the same reasons mentioned above. Hybrid seed has to be made each year, for if planted a second time, the yield is seriously decreased.

5) **Insect Pests and Disease**

During the early years of Thailand's corn industry, the need to use defense practices against corn insects and corn diseases was not great. As the crop become more intensively cultivated, however, both insects and diseases rapidly increased. Several corn pests are now serious and means for their control must be found.
B. The Need for a Concerted Action Program

By 1960 it was recognized that a serious effort was needed to solve the developing problems confronting the corn industry. It was evident that only a combination of efforts would achieve required results.

The Ministry of Agriculture asked USOM for assistance. The USOM program had played a major role in the development of the corn industry. Now the Ministry hoped the USOM Crops Development project would be equally effective in face of the new problems which confronted corn production.

Variety introduction and testing, the establishment of proper seeding dates, and the investigation of planting and cultivation practices, entailed a simple type of research. Solutions to the new problems, however, required skilled technicians, detailed procedures and advanced research methods. In 1960 Mr. Charles Breitenbach was transferred from Latin America to be Agronomy Advisor in Thailand. He had been associated with the Rockefeller Foundation's Inter-American Corn Projects and served last in Guatemala. There he had worked with Tiquizate Golden Flint, the "Guatemala" corn of Thailand.

The Agronomy Advisor arranged a second introduction of "Guatemala" corn. One hundred lbs. of Tiquizate Flint corn was purchased by USOM and airshipped from Guatemala in June of 1960. The seed was multiplied at Pakchong by the Department of Agriculture. Comparative tests proved that it was identical to the previous 1952 introduction. The new introduction segregated to light colored flint corn in the same proportion as did the original introduction. It was identical in appearance and its productive capacity proved to be the same as the original "Guatemala" corn in comparative yield trials.
This comparative study crystalized two facets. First, it was evident that the decreased yields obtained on an ever greater number of farms in the Pakchong area were not the result of a loss in yield potential. Second, the segregation to light colored dent corn was an inherent character of the variety. This proof that there had been no "degeneration" in either quality or productivity made the need of a breeding program to improve yield and to fix quality self-evident. 

\[ \text{In spite of the 1960 comparative trial the belief has persisted that Guatemala corn has deteriorated and that this accounts for its segregation. Because of pressure from Japanese importers to maintain the golden flint character, the Ministry of Commerce has been insistent that large amounts of Guatemala Corn once more be introduced from Central America and that the old seed be replaced with new. Under this pressure the Ministry of Agriculture had a third introduction of 500 lbs. introduced for multiplication. Comprehensive trials on seed characters, plant morphology and yield at the Bangkhen Experiment Station have demonstrated again that the three introductions are each identical.} \]
C. The Initiation of the Coordinated Program for Corn Improvement

In 1960 the question was debated whether Thailand should breed a double hybrid as the Oregon Contract team suggested. The USOM Agronomy Advisor did not think so; instead he favored a program for the development of synthetic corn varieties. In Latin America the Rockefeller Foundation had had excellent success with such programs. The conditions in Thailand were not dissimilar.

Mr. Breitenbach made contact with the Rockefeller Foundation and learned that Dr. E. J. Wellhausen, the Director of the Mexican Corn program, was to visit India. The Ministry of Agriculture invited him and the Foundation's corn breeder in India, Dr. Ernest Sprague, to survey the corn situation in Thailand. In October 1960 a meeting was held with Mr. Insee Chandrastitya, the Rector of Kasetsart University, Prince Chakrabandhu Pensiri, the Present Director General of the Department of Agriculture, Dr. Wellhausen, Dr. Sprague and Mr. Breitenbach. A program of coordinated research for corn improvement was developed.

The Rockefeller experts agreed to assist in outlining and guiding such a program on two conditions. They requested that USOM sponsor the program and provide a resident technical advisor, and they insisted that there be only one corn program. The Ministry of Agriculture and Kasetsart University were requested to integrate their efforts under the coordinated program.

USOM agreed to the arrangement since it could not on its own direct and support a program of the scope proposed. As it had been associated
with the corn development program since its initiation, it was anxious to support the joint venture. Since 1960, USOM funds for corn research from both the University Contract and the Crop Development Project have been spent jointly on the coordinated program. Rockefeller funds as well as contributions from the Thai National Research Foundation, the Ministry of Agriculture and Kasetsart University have also been used.

On subsequent trips Dr. Sprague set up a research program and the Ministry of Agriculture provided a one hundred rai tract of land at Prabuddhabat, in the province of Saraburi, for use as the coordinated program's corn center.

The corn breeding activities under the program include: (1) controlled mass selection in "Guatemala" corn, (2) the production of a synthetic corn from "Guatemala" germ plasm and (3) the development of flint and dent synthetic varieties from superior Caribbean germ plasm. In addition to corn breeding, there is a program for the production of certified "Guatemala" corn seed. Work in corn fertilization and pest control are also part of the coordinated research.
D. The Development of a Synthetic Variety from Guatemala Germ Plasm.

This is a program to obtain a pure golden flint corn with an improved yield potential out of "Guatemala" germ plasm. It makes use of the inbreeding procedure so as to break down the germ plasm complex into individual components. These components are tested for their yielding ability. The superior components are saved and recombined into a new "synthetically composed" corn containing only superior germ plasm. In the process the poor yielding components are systematically strained out and eliminated.

This synthetic system utilizes only first generation inbred lines. For that reason the difficulties of maintaining weak advanced generation inbreds do not arise. The first phase of the program is to select a number of individual plants within a multiplication plot; each must be superior in appearance and free of disease or insect attack. About 400 such plants are selected. The male and female flowers are bagged and a self-pollination process is carefully employed. At the time of harvest a cursory examination is made of the selfed ears. Those which demonstrate poor characters, such as malformation or disease, are eliminated. Those that do not have a good golden color or which are dent in type are also eliminated.

The selected ears are degrained and carefully labelled. The grains in each case are separated into two equal parts. One half of the grains of each selfed ear is stored in a cold room where germinability is carefully maintained. These are the "remnant seeds" which will be used to make up the synthetic after a process of testing and elimination.
The second stage of the synthetic breeding program is to produce top cross or "half-hybrid" seed. The latter is used to test the good yielding components in order to strain them off from the poor germ plasm in "Guatemala" corn. In each case, the "non-remnant" half of the seed of every selfed ear is planted in an individual row. It is systematically hybridized with the open-pollinated "Guatemala" variety.

The third stage is to test the "half-hybrids", each composed of a once selfed line fertilized by "Guatemala" pollen. Such "half-hybrids" are tested in comparative yield trials in which the non-improved "Guatemala" variety serves as the control. At the time of harvest, the yield of each half-hybrid is weighed and compared by the analysis of variance method. In every case where the "half-hybrid" yields significantly more than the original Guatemala, the yield trial has proven that the once selfed female parent possesses superior germ plasm than the non-improved "Guatemala" corn. Where the "half-hybrid" yields less than the original "Guatemala" the trial proves that such a once selfed female parent possesses a significantly inferior germ plasm component. With this the first half of each once selfed line has served its purpose. (Future work in the synthetic process takes use of the "remnant seed" stored in the cold room).

The fourth stage of this procedure is to eliminate those one generation inbred lines which did not produce "half-hybrids" significantly superior in yield to the "Guatemala" variety. These are discarded. Only once selfed lines which have produced superior "half-hybrid" seed is retained. This superior "remnant seed" is thoroughly mixed, and planted in
isolation blocks for multiplication. The product is a first cycle synthetic variety.

Such seed is now being multiplied at the Prabuddhabat Corn Center. After the first cycle synthetic "Guatemala" corn has been increased the process will be repeated a second time to produce a second cycle synthetic so as to further select a highly productive population from Synthetic I. This seed (Synthetic II) will also be propagated and the process repeated for the third time to produce a third cycle synthetic, and then a fourth cycle synthetic, etc., until no further increase in yield can be achieved by the described method.

The synthetic method has the advantage that seed can be multiplied and released after each cycle. Such seed when maintained in isolation, to prevent contamination from foreign pollen, will breed true as does a pure variety. It has many of the advantages of hybrid seed.

In their Latin American programs, The Rockefeller corn breeders have obtained about a $\frac{151}{1}$ increase in yield during the first and second breeding cycles. In later synthetic cycles increases in yield have been found to taper off because the germ plasm becomes more and more selectively purified after each cycle of breeding.

\[\text{Preliminary investigations on the first cycle synthetic developed at Prabuddhabat under this activity also indicate that a yield increase of about } 15\% \text{ over the parent variety, open-pollinated "Guatemala", has been achieved.}\]
E. The Development of a Synthetic Variety from Caribbean Germ Plasm

This has been a program for the introduction and testing of new germ-plasm types with known high production abilities. The program was initiated in the following way.

Tester varieties from the different ecological zones of Latin America were grown and compared under Thailand's conditions in a comparative yield trial. The trial demonstrated that the material from the Carribean area of Latin America (Northern-South America, Central America and the Carribean Islands) was well adapted to local conditions. On the basis of this trial, the Rockefeller Foundation supplied the coordinated program for corn improvement with its superior yielding indigenous varieties from the area. The introductions contained both flint and dent varieties.

On arrival in Thailand the introductions were separated into dent and flint populations. These populations have been planted separately in isolated blocks and allowed to intercross for four generations. Each "homogenized" population now is ready for improvement by the "synthetic selection" method described in the previous section.

Within these populations there exists the probability of isolating higher yielding synthetic types than is expected by the same procedure with "Guatemala" corn alone. Among the flint and dent complexes there should be a wider germ plasm base for the selection of good components than when only "Guatemala" germ plasm is used.
F. The Development of a Superior Guatemala Corn Type by Controlled Mass Selection

This is the simplest of the three breeding procedures. It is practised at the Prabuddhabat Station and 10 other agricultural research stations throughout Thailand.

The process is one of controlled selection within the Station's "Guatemala" seed-corn multiplication plots. The plots are systematically divided into minor blocks each 5 meters by 10 meters in area. During the entire growing period intensive care is taken to rogue out of the multiplication plots all off-type plants, all diseased plants, plants attacked by insects and any plants that have poor standing ability.

At the time of harvest the ears in each individual block are harvested separately and the 10 superior appearing ears of flint type are selected by sight. Each of these ears is degrained and the grain weighed independently. In every block the grain of the three ears that produced most yield by weight is saved. This selected seed from all the blocks is then bulked together. It becomes the breeder's seed which is used for the breeding plots the following year.

The procedure is effective only if the breeder's prejudice is eliminated from the selection process. Thus the three superior ears from every block must always be used as part of the bulk seed. This applies equally in those cases where the three ears appear greatly inferior to the ears of other blocks. Such a procedure is the control that eliminates a breeder's temptation to choose all selections from a few superior blocks in the field where high yield may in fact be due to a special condition such as high fertility and not to the innate yield potential of the individual plant.
In the controlled mass-selection breeding program two generations have been grown at each station. The third generation is being selected during the 1963 growing season. At most of the 11 stations, there has been achieved a 3% increase in yield each generation. The process is to be continued until no further increases can be obtained by the selection procedure.
G. The Seed Certification Program

The serious concern which has been expressed by the Japanese importers of "Guatemala" corn in Thailand has already been mentioned. PART II A., "The Problems Related to National Corn Production". They are critical because the variety is not a true-breeding flint. The Thai Government is also concerned because each year a certain percentage of "Guatemala" corn segregates to a light yellow dent-type grain. In 1962 a seed certification program was initiated by USOM and the Department of Agriculture to control that situation. The seed certification program is practised in the following manner:

Each year the mass ears are separated from the selected ears at the eleven agriculture stations where controlled mass selections are under way. The mass ears are inspected to eliminate any off-color dent ears. They are dried, degrained, and the seed is treated with insecticides and fungicides. This is the foundation seed which is supplied to certified seed corn producers the next year.

In 1962, 51 seed certification producers were supplied enough foundation seed to grow 250 rai of certified seed. Their multiplication plots were carefully inspected by agriculture officials to assure that the certified seed farms were in isolated areas and that recommended agronomic practices were employed in the production of their certified corn seed. The officers inspected each field and eliminated off-type plants.

At harvest, an ear elimination was made for the purpose of discarding all off-color, soft-grained ears. Samples of the grain were taken to the Bangkhen Seed Testing Laboratory. There they were tested for humidity, germinability, disease contamination, insect damage and other undesirable
properties. Where the seed passed the rigid inspection requirements, the certified seed farmers were given special seed certification tags and allowed to sell their corn as government inspected, officially certified "Guatemala" seed.

Seventy tons of certified seed was purchased by the Ministry of Agriculture in 1961 at 10% above the market price. It was distributed by the Ministry's Extension Service for resale to cooperating farmers at cost. This certified seed proved sufficient to plant an estimated 23,000 rai of improved "Guatemala" corn.\(^2\)

In 1963, the program is being repeated and it is hoped that close to 100 tons of certified seed will be purchased by the Ministry of Agriculture this year. Certified seed that is not purchased by the Ministry of Agriculture may also be sold to private dealers together with government inspection tags at the government bonus price.

---

\(^1\) In 1960 and 1961 the USOM Crop Improvement Project purchased with commodity funds the equipment necessary for the Department of Agriculture to set up a complete seed analysis laboratory. This was in anticipation of the seed certification program. Two Department officials were trained under the USOM participant program in seed technology. They have now returned to Thailand and are now in charge of the seed laboratory.

\(^2\) Two to two and a half kilos of "Guatemala" seed corn is the recommended seeding rate for each rai of land.
H. The Soil Fertility Program

Under the coordinated program for corn improvement, a very heavy application of fertilizer is being used on all breeding plots. This is equivalent to 200 kgs. per rai of a 12-12-6 fertilizer formula. Thus the available nutrients are: 24 kgs. N, 24 kgs. of $P_2O_5$ and 2 kgs. of $K_2O$ per rai.

This heavy application of fertilizer is utilized to achieve a good response to fertilizer usage in the new varieties that the program will develop.

Preliminary studies have indicated the probability that open-pollinated "Guatemala" corn responds poorly to fertilizer usage. During many generations of natural-selection the variety's ability to respond to fertilizer may have become lessened. The germ plasm components capable of responding to fertilizer applications have probably become so masked by other components incapable of such response that "Guatemala" corn is no longer highly responsive.

It is thought that by maintaining high fertility levels in our breeding plots, the new material selected will be capable of greater fertilizer utilization. Chemical fertilizers will then have an improved effect on increasing the yields of our new releases than they do now on open-pollinated "Guatemala" corn. However, when unfertilized, the new releases will still produce substantially more than does the old variety.
Two specific fertilizer trials are being carried out by the coordinated program. The first trial is a comparative yield test of standard fertilizer formulas to obtain further accuracy in the use of fertilizer applications and to learn more about the fertilizer rates which should be recommended to farmers.

The second trial is a calibration of the actual soil nutrients in representative corn soil types with the specific needs of a corn crop in its use of available N, P₂O₅ and K₂O.
I. The Crop Defense Program

During 1962 two surveys were undertaken. The first was a survey of the diseases of corn. The second was a survey of the insect pests of corn. These surveys will have the effect of indicating which diseases and which insect pests may have epidemic potentials in future years. They will provide the opportunity to test the effectiveness of both chemical and biological control measures in preparation for the time when such controls may be critically needed.

The survey and identification work on corn diseases indicates that five diseases were already widespread in 1962. These are: Ear Rot, Leaf Blight, Rust, Collar Rot and Smut. Also Bacterial Top Rot, a very destructive disease, was found in two localized corn producing areas. Investigations are under way by which it is hoped to prevent the disease from spreading.

The insect survey has identified over forty species of insect pests of corn. Of these sixteen species were found to cause serious destruction. One of the most serious is the Corn Borer (Ostrina nubialis). During the survey an effective corn borer insect parasite was discovered. The life cycle of the parasite is being studied with the intention of multiplying it in the laboratory and then releasing it as a biological control.

\[1\] In the 1962 survey, the Bombay grasshopper was observed and noted to be a serious potential pest. In 1963, it assumed serious epidemic proportions in Lopburi Province. USOM played a major role in the air-borne spraying which contained this epidemic.
J. The U. S. Contribution to The Crop Development Project

The total expenditure on the Crop Development Project in dollars and baht from 1951 through FY 1962 was an equivalent of $7,129,000. Of this, $2,491,000 was the U. S. dollar contribution. The counterpart contribution in baht was equivalent to $2,957,000. The Ministry of Agriculture's contribution from the national budget equalled $1,681,000 in baht equivalent, plus land and facilities.

It is estimated that approximately one third of the U. S. dollar contribution to crop development was spent on American technician's salaries and expenses; one third was spent on training Thai participants, and one third on the purchase of commodities for the program.

By 1963, twelve American Agronomy Advisors had served with the Project. Eight of these each served for one two-year tour. There were three Agronomy Advisors who served for two tours, or four years each, and one who served for three tours or a total of six years. In addition, three Entomology Advisors served with the project for one tour each and two Soil Scientists each served for one tour.

Under the project through 1962 the following numbers of participants had been trained abroad in the following fields for six months or more:

1) Planting Breeding  -  10 participants
2) Agronomy         -    7 "
3) Rotation Crops    -    3 "
4) Fertility Usage   -    8 "
5) Crop Defense      -   15 "
About sixty participants had received third country training for short term periods, either at conferences or on specially arranged programs.

The commodities purchased out of the dollar contributions, in order of importance, were: agricultural equipment, scientific and laboratory equipment, seeds, fertilizers and pesticides, and vehicles.

About one-fourth of the counterpart contribution was used to pay the American technicians' costs and allowances. About three-fourths of the counterpart contributions have been spent on the actual operational expenses of the project.

The Ministry of Agriculture's contribution was employed to pay the salaries of local Ministry personnel and the maintenance of the Agricultural Research Stations.

The Crop Development Project has worked on a variety of field crops, as well as vegetable and fruit crops. It is not possible to determine the percentage of funds utilized in corn research. However, it is estimated that not more than 10% of the total project expenditures have been used for corn research.