PEST, PATHOGEN, AND WEED CONTROL FOR
INCREASED FOOD PRODUCTION

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If the ideal of assured "Food for All" is to be attained, it will be necessary to do a better job of preventing the debilitation or destruction of crop plants by noxious weeds, voracious animals, and devastating plant diseases. For these destructive agents continually tend to nullify the constructive efforts to increase food production.

Food production per unit area of land has been increased greatly in advanced countries during the past half century by producing continually better varieties of food plants and by devising better methods of soil cultivation and fertilization. Unfortunately, however, bad weather, pests, and pathogens too often prevent the better-bred and better-fed varieties from realizing their full productive potential. The destructive effects of these inanimate and animate enemies of crop plants must be prevented or reduced by more widespread and effective use of materials and methods now available and by devising better ones for the future.

Education and research are man's most potent allies in this continuous fight against the destructive agents that continually menace his food supplies and often deplete them dangerously; ignorance and apathy are his most powerful enemies. Although phenomenal progress has been made in fighting pests and pathogens, the fight against them is far from won.

Even in a relatively advanced country like the United States, weeds, insect pests, and plant diseases reduce the potential annual crop production by more than 20 per cent, and the losses in many of the less-advanced countries are considerably higher. In the United States we are still using the equivalent of 75 million acres of crop land to feed weeds, insects, and plant pathogens instead of human beings. Countries that produce a surplus may be able to afford such losses yet a while, but food-deficient countries cannot. The situation often is aggravated by the tendency of many insects and plant pathogens to become devastatingly destructive periodically. Outbreaks of insect pests and the epidemic development of plant diseases often destroy huge quantities of man's basic food crops. In two successive years, 1953 and 1954, stem rust epidemics destroyed one fourth of the bread wheat and three fourths of the durum wheat in the principal spring wheat area of the United States. Losses of this magnitude are catastrophic in countries that are always hungry and often on the verge of famine, as is illustrated by the death of upward of a million people in India, about a decade earlier, because Helminthosporium blight destroyed much of the rice crop in large areas of production. The control of the living enemies of crop plants often makes the difference between food and famine.

The control of pests and pathogens of the principal cereal food grains—wheat, rice, maize, sorghums, and millets—would add 200 million tons annually to the billion tons now produced. Assuming an average of about 45 lb to a bushel, there would be about an additional 2.7 bushels, or 120 lb, a year for each of the world's 3.3 billion people, enough to furnish each person 2000 calories for about 100 days. These data are based on an estimated 20 per cent annual loss, which is conservative in view of the fact that calculated average losses are somewhat higher in the United States. Although plant protection specialists sometimes are accused of overesti-
mating crop losses, there is evidence that there has been a tendency to underesti-
mate rather than overestimate them.

The magnitude of potential gains from controlling weeds, insects, and diseases separately can be illustrated by the results of experiments involving sugar beets, rice, and wheat.

"How much does one weed cost?" is the title of a recent article on the effect of weeds on sugar beets.¹ The author's aim was to find out whether it was economical to hand-pull large weeds that had been missed in thinning the beets and at the first hoeing. As the author of the article states the problem, "... But when there is a light stand of weeds the question is often asked—'How much are they costing me?' With increasing labor costs, growers are less concerned about the appearance of the field than they are about the net returns from the sugar beet crop." As stated by the author, "The results of this test when harvested on February 26, 1966, were as follows:

<table>
<thead>
<tr>
<th>No weeds</th>
<th>Tons beets per acre</th>
<th>Tonnage reduction</th>
<th>Loss per acre</th>
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<tr>
<td>One weed for 6 beets or 17 weeds per 100 ft</td>
<td>31.5</td>
<td>2.9</td>
<td>$36.68</td>
</tr>
<tr>
<td>One weed for 3.3 beets or 30 weeds per 100 ft</td>
<td>29.6</td>
<td>4.8</td>
<td>$60.72</td>
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The author concludes: "There was no measured effect of the weeds on sugar percentage, but a costly reduction in beet yield was indicated.

"The loss of 4.8 tons to the acre amounts to a reduction of approximately $60.72 in gross income. When the cost of pulling the weeds is considered at $23.00 per acre as well as the additional harvest and hauling costs, the grower netted about $29.30 per acre by pulling all of the weeds.

"When the weed population is only one weed for every six beets, there is still $8.60 to be gained, even at a cost of $23.00 per acre.

"It might be well to bear in mind that for each weed left in the field, a bright new penny has been lost forever."

The emphasis in this illuminating article is naturally on the economics of weed control, as the experiments were made where food is abundant and labor costs are high. In countries where labor is cheap and food is scarce, the emphasis could well be placed on the 13 per cent loss in production of beets, or, stated in reverse, on the 13 per cent increase as the result of pulling the weeds that survived the early weeding operations.

The importance of weed control is further illustrated by the results of experiments on weeding rice.² As stated in The I.R.R.I. Reporter, "Recent cooperative experiments conducted in five Asian countries demonstrated that handweeding increased yields by an average of about 45 percent over the plots not weeded. There can be no doubt that weed control is necessary, but there are many ways of going about it—especially since the advent of selective herbicides."

During the past few years the Rice Research Institute has tested about 200 commercial weed killers and has compared them in various combinations with traditional hand-weeding methods. In experiments made during the 1965 wet season, plots were sown with a high-yielding variety of rice and with weed seeds, principally water grass (Echinochloa crusgalli), and then treated in 12 different ways with respect to weed control. Nonweeded plots yielded 1,611 kg of rice per hectare
as compared with 5,204 kg/ha, the highest yield, from plots that had been hand-weeded twice. Thus, weeds had caused a loss of about two thirds of the crop in nonweeded plots. The article states: “Although the highest yield was obtained from the treatment handweeded twice, this is clearly an expensive method of control if labor has to be hired: it yielded 47 kg of rice for each U. S. dollar spent compared with about 180 kg/dollar for some of the chemical treatments.” Where food is scarce and labor cheap, would it be better to hand-weed and get an additional 3600 kg of rice per hectare or would it be better to make one application of the best chemical weedicide and get about 2100 kg additionally? The conclusion in the article is that weed control is essential, but that: “The method of weed control selected will depend on the labor situation, availability and cost of herbicides, and other factors that vary from country to country….” Weed control is indeed essential!

Clearly, then, weeds alone are a major depressive factor in food production. Most of them can be controlled, but research must determine the best ways of controlling each of the numerous kinds under the numerous different kinds of conditions that exist in the world that they try to dominate.

The magnitude of damage caused by insects and the benefits derived from effective control measures are well illustrated by experiments at the International Rice Research Institute.

Stern borers of several kinds, belonging to the genera Chilo, Tryporyza, and Sesamia, annually destroy a considerable percentage of the rice crop in most of Asia. In the past, few rice farmers have used the available control measures because they required spraying the growing crop repeatedly with chemical insecticides. But, “In experiments at the Institute in 1963, plots receiving the most effective insecticide treatments yielded 87 percent more grain than untreated controls during the dry season and 97 to 102 percent more during the wet season.” The minimum increase in yield as a result of partial control by spraying with the best insecticides amounted to about 20 bushels an acre, more than the present average yield in India. Actual maximum increases in yield of treated plots over the controls in various experiments are shown by the following typical yields, in kilograms per hectare: 7,650 vs. 4,082; 3,575 vs. 1,805; 4,145 vs. 2,045. The increases amounted to 3,568; 1,770; and 2,100 kg/hectare, respectively. Surely such increases in yield are a potential godsend to hungry millions of rice eaters.

Better still, “The entomologists obtained further evidence to support their original findings that the gamma isomer of benzene hexachloride (lindane), when used as a systemic insecticide, provides excellent control of the rice stem borers. Protection of plots from borer damage in some instances increased yields by as much as three tons per hectare,” according to a recent report from the I.R.R.I. Four tons more rice per hectare! And the lindane treatment is so easy to apply that every rice farmer can use it. Research has paid big dividends; there can be “miracle drugs” for food plants as well as human beings.

The control of plant diseases, too, can pay big dividends, as illustrated by recent data obtained at the Canada Department of Agriculture Research Station, Glenlea, Manitoba, and published in Grain Market Features under the title “How the battle against rust is being won.”

Data on acre yields, and other pertinent data, are given for four wheat varieties
grown in plots at the Glenlea Station in 1964. To understand the significance of the results it is necessary to know something about the varieties.

Marquis, Canadian-bred, was the predominant wheat in the spring wheat region of the United States and Canada about 50 years ago because of high quality and early ripening, which enabled it to escape heavy attacks by stem rust (Puccinia graminis) in some seasons. It succumbed, however, in the devastating epidemic of 1916 and was soon replaced largely by the more resistant variety Ceres, produced cooperatively by the U. S. Department of Agriculture and the North Dakota Agricultural Experiment Station. But Ceres in turn succumbed to stem rust and leaf rust (Puccinia rubigo-vera var. tritici) in the widespread epidemic of 1935. Thatcher, produced in Minnesota by federal and state agencies, was released in time to demonstrate a high degree of resistance to stem rust in the 1935 epidemic. Although susceptible to leaf rust, it retained its resistance to stem rust until 1950, when a new parasitic race, 15B, became prevalent. It was soon supplanted by the new Canadian variety, Selkirk, which has been the predominant variety in the spring wheat area for about a decade. Manitou is a relative newcomer, but its record so far is eloquent of its promise. The four varieties for which data are given, then, represent successive steps in rust control, especially stem rust, which is a more vicious killer than leaf rust.

The data in the following table show how destructive wheat rusts can be, progress in controlling them by means of resistant varieties, and what could have happened if research and experimentation had not been continuous.

More wheat and better wheat! But it is a constant fight to produce it because it has many shifty enemies, and continuous research is necessary to detect and arrest them before they cause disasters.

The foregoing case histories illustrate the magnitude of losses caused by weeds, insects, and plant diseases and the actual or potential benefits of control measures. What are the prospects for realizing these potential benefits generally? They are good if research and education are organized on a scale commensurate with the magnitude and complexities of the problems. They are poor if advanced countries become complacent and if emerging countries fail to develop adequate research and educational organizations of their own.

The need for more and better research and experimentation is greater than ever because of the increasing pressure of population on food supplies and land resources and because the problems of crop protection are diverse, complex, and often in a state of flux. There are some 500 species of weeds of major importance in the United States alone. There are thousands of species of insects that cause direct damage to economic plants or act as agents of dissemination and inoculation of plant

<table>
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<th><strong>TABLE 1</strong> COMPARATIVE PLOT RESULTS (1964)</th>
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<tr>
<td>Marquis*</td>
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<tr>
<td>Yield, bu/acre</td>
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<tr>
<td>Weight, lb/bu</td>
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<tr>
<td>Price at Winnipeg</td>
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<tr>
<td>Net return per acre (gross minus $20 production cost)</td>
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* Badly affected by both leaf and stem rust.
† Heavily infested with leaf rust and carried some stem rust.
‡ Carried an appreciable amount of leaf rust but no stem rust.
§ Carried only a small amount of leaf rust and no stem rust.
pathogens. Among the pathogens, more than 200 kinds of viruses have been discovered and studied more or less thoroughly during the past 50 years. At least 200 species of bacteria cause diseases of all the major groups of crop plants. Of the approximately 10,000 known species of nematodes, or eelworms, several hundred are known to attack some 2,000 kinds of plants. An estimated 25,000 of the approximately 100,000 recognized species of fungi are parasitic. Not only is there a great diversity of species of pathogens but there is even greater diversity within many of the species.

Most species of pathogenic fungi are vast confederations of biotypes that have some characters in common but that differ in others, including physiology and pathogenicity. New biotypes are continually being produced by mutation, by sexual recombinations, or by other kinds of genetic changes; accordingly, most species comprise a diverse and changing population of biotypes. Plant pathologists try to identify and group biotypes that differ in pathogenicity into physiologic races. As one example, about 400 physiologic races of wheat stem rust (Puccinia graminis var. tritici) have been identified by their pathogenic effects on about 20 "differential varieties" of wheat. A wheat variety may be immune from some races, moderately resistant to some, and completely susceptible to others. No known wheat variety is immune from all known races, but no known wheat-growing area is infested by all known races. Consequently, the problem is to breed varieties with resistance to the races that are prevalent in the areas for which the variety is designed. To breed intelligently, however, the breeder must know the identity, pathogenic peculiarities, and population trends of the races against which he is breeding. And this requires continuous research.

Many pathogenic viruses and bacteria also comprise "strains" or races that differ in general or specific pathogenicity, and the race problem is not absent among the nematodes. Although the existence of races, or strains, within species is of greatest importance in breeding and maintaining disease-resistant varieties, it sometimes complicates other methods of control also. At any rate, most pathogens are dynamic and this is one of the reasons why disease situations are seldom static.

The problem of new pests and pathogens is continual, partly because of genetic changes in the pathogens within a region that they have long occupied or because of the introduction of old organisms into new areas. Wind, insects, and man can be very effective agents of long-distance dissemination, man being one of the worst offenders against his own interests.

The danger of new pests and diseases is probably greater now than ever before. The wind probably does not blow harder than it did a few decades ago, nor do insects fly faster, but man certainly travels faster and more extensively. The more extensive and rapid exchange of propagative plant materials facilitates the more rapid exchange of pests and pathogens also. Recent history records the contamination of many agricultural areas with destructive invaders from afar, and, unfortunately, zealous but scientifically unsophisticated "do-gooders" can easily aid the invaders. Knowledge and vigilance are essential in restricting the dangerous extension of pests and pathogens beyond the boundaries within which they now exist.

The prospects for the future? The prognosis is excellent provided there is a realistic appraisal of difficulties and continual efforts to overcome them. To capitalize fully on presently known methods of increasing food supplies by van-
quishing their enemies will require widespread education; to devise better methods for increasing future food supplies still more will require continuous research and education, for pests and pathogens are indeed "shifty enemies." There is no panacea for controlling the numerous and diverse enemies of the numerous and diverse crop plants. And there is no one guild of crop-protection specialists who are competent to prescribe for all the special cases, yet precise prescriptions are needed, because the wrong procedures may do more damage than good, just as the wrong prescriptions for treating animal or human diseases may have unfortunate or even fatal consequences.

In the recent past there has been phenomenal progress in the development of better and still better chemicals to control weeds, insects, and plant pathogens. Many of these chemicals are very specific in their effects, not only on different pests and pathogens but also on the crop plants themselves, and must therefore be used with knowledge and discretion. But there can be revolutionary progress in chemical control if research is commensurate with the possibilities. Yet there are many insects and plant diseases that can not now be controlled economically by chemicals; resistant varieties are the only recourse.

The ideal way of controlling insects and diseases would be by means of resistant varieties, for the more self-protection man can incorporate into his crop plants, the more he himself is relieved of the burden of protecting them. While man is breeding resistant varieties, however, nature is breeding parasitic races or their equivalent on a far vaster scale. Man's only advantage is his scientific intelligence. Resistant varieties have already made great contributions, even though many of them in the past have succumbed sooner or later to new pests or pathogens or to new races of old ones. Research has already revealed the basic reasons why many pathogens are such insidious, shifty, and resourceful enemies. But research must be continuous because pests and pathogens are continuous and are continually changing and menacing resistant varieties with new or different parasitic races. To interpose new and more effective kinds of resistance against them is neither an easy nor an impossible task. But to checkmate pathogens better, we must learn to know them better. We must know them well enough to anticipate new attacks, and be ready with new varieties to resist them. With enough research, it should be possible to produce varieties with universal resistance or tolerance to some of the most destructive enemies of crop plants. This is the goal.

Plant protection is essential in safeguarding and increasing food supplies. The potential future contributions are far greater than the great contributions of the past. But research must not be curtailed; to curtail it would be not only unwise but reprehensible, for millions of human beings depend upon research and yet more research to alleviate present hunger and to ensure against it in the future.

3 International Rice Research Institute, Annual Report (Manila, the Philippines: International Rice Research Institute, 1963), pp. 119–134.
4 Rockefeller Foundation, Program in the Agricultural Sciences, Annual Report 1964–1965, p. 244.