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†THE IMPACT OF THE GREEN REVOLUTION ON PLANT PROTECTION IN TROPICAL AND SUBTROPICAL AREAS

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The earliest use of the term 'integrated control', at least in its pest control sense, dates from June of 1954 (Smith and Allen 1954). Thus, the history of integrated control would appear to have spanned little more than 17 years. Until now, most discussions of the origins of integrated control have emphasized the over-dependence on and the over-use of chemical pesticides subsequent to World War II and the unfortunate and unfavourable consequences which resulted from the use of these chemicals. These unfavourable consequences involved particularly the development of insect populations resistant to pesticides, undesirable residue levels on food crops, impact on wildlife, the rapid resurgence of target pest populations following treatment, and outbreaks of unleashed secondary pests (Smith and Reynolds, 1971). All of these repercussions and the steps taken to adjust for them culminated in excessively high costs for plant protection. Then as the story goes this series of unsavory events was coupled with the wisdom of a few ominiscient soothsayers; and the integrated control came into the world. Another somewhat different account of the historical development of integrated control as related by one of our British friends describes it as a mixture of 'idealism, evangelism, pursuit of fashion, fund-raising and even empire-building. The movement has indeed acquired the impetus and character of a religious revival .. ' (Price-Jones 1970).

There may be some elements of veracity in both of these versions of the modern origins of integrated control but I believe the fundamental origins of integrated control are more remote in history. It is of these more ancient origins I had planned to talk to you this morning. In my view, the origins of integrated control and its philosophy can be easily traced to a small group of entomological pioneers who were leaders in our profession in the latter part of the nineteenth century and the first decades of this century. Among these pioneers, we must place in first place that great entomologist and ecologist Professor Stephen A. Forbes of the Illinois Natural History Survey (Forbes 1887, 1915; Metcalf 1930). Along with Forbes, we must add the names of Benjamin D. Walsh, State Entomologist of Illinois and mentor to C. V. Riley, (Howard 1930; Riley 1870; Walsh 1864, 1866a, b; Weiss 1936), and Professor Charles W. Woodworth, a student of Forbes and the developer of economic entomology in the University of California (Essig 1940, 1941; Smith

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1971: Wickson 1918; Woodworth 1896, 1908). Professor William A. Riley of Cornell University and of the University of Minnesota (Hodson 1963; Jellison, Philip and Wallace 1953) whom we honour this morning, and several other early entomologists (Isely 1937; Townsend 1926), also recognized and advocated the importance of an ecological base to economic entomology.

These days when we are taken up with many glamorous new insect controls, it seems worthwhile to pause and honour these early entomologists. And so, I had planned to talk this morning of these great men and their works and how starting more than a hundred years ago they had developed the basic principles of what today we call integrated control. In fact, earlier this year and prior to an extended trip to Southeast Asia I had prepared my lecture on this topic. However, my experiences over the past three months in Southeast Asia have made me set aside my prepared discussion and I wish now to talk to you on quite a different topic. As I turn away from an historical analysis of the origins of the integrated control to a much more timely topic, I hope you will recall the principles and philosophy established by the founders of our profession in the United States.

I am sure that you have all heard of the 'Green Revolution', and the tremendous food production gains in wheat, rice and maize that have been achieved within the past five years in several developing countries and the great potential of the Green Revolution in the future of these countries.

To refresh your memory on the facts of the Green Revolution, let me quote a rather conservative statement of Norman E. Borlaug given in Rome recently (Borlaug 1971): 'The only crops which have been appreciably affected up to the present time are wheat, rice and maize. Yields of other cereals, such as sorghums, millets and barley, have been only slightly affected; nor has there been any appreciable increase in yield or production of the pulse or legume grain crops, which are essential in the diets of cereal consuming populations. Moreover, it must be emphasized that thus far the great increase in production has been in irrigated areas. Nor have all cereal farmers in the irrigated areas adapted and benefitted from the use of the new seed technology. Nevertheless, the numbers of farmers, small as well as large, who are adopting the new seeds and new technology is increasing very rapidly, and the increase in numbers during the past four years has been phenomenal. Cereal production in the rainfed areas still remains relatively unaffected by the impact of the Green Revolution, but significant change has been made in several countries during the past three years. Despite these qualifications, however, tremendous progress has been made in increasing cereal production in India, Pakistan, and the Philippines during the past three years. Other countries that are beginning to show significant increases in production include Afghanistan, Algeria, Brazil, Ceylon, Indonesia, Israel, Iran, Kenya, Malaysia, Morocco, Thailand, Tunisia, and Turkey. The significance and magnitude of the impact of the Green Revolution is shown by the wheat production in Pakistan. It rose from the base figure of 4.6 million tons in 1965 to 6.7 million tons in 1968, to 7.2 million tons in 1969 and 8.4 million tons in 1970.

There is a world agricultural revolution in progress; but are you aware of the implications of this revolution for entomologists, plant pathologists and others conversed with plant protection?

The plant protection specialist, whether he be plant pathologist, entomologist, weed scientist, nematologist or whatever, has always proclaimed loudly and clearly on any available platform the importance of his scientific speciality in plant protection —only occasionally he consented to place his speciality and plant protection in a more honest perspective as merely a critical and essential part of crop production. But today and most importantly, representatives of other scientific disciplines and those with other interests (even those whose orientation is primarily political) are coming to realize the greatly increased significance of plant protection and are speaking out on its critical importance in the modern world. This has occurred in the tropical and subtropical agricultural areas because of the Green Revolution.

This Green Revolution is of great consequence not only for its impact on food production over the past few years but also for the continuing changes it will produce in the economy and in the social structure of the less developed countries of the world. The Green Revolution is just commencing in many countries but nevertheless it has produced already major modifications of many agroecosystems particularly in Asia. The piece of these changes is rapid and seems to be going on at an ever-increasing rate.

Often the Green Revolution is equated with the introduction of the new high-yielding grain varieties into the agriculture of developing countries of the tropics and subtropics. This is a great over-simplification. In reality it is an evolution of the entire agricultural matrix. In this evolution, there is a shift towards monocultures—not only vast acreages of a single crop plant—but vast acreages of a single plant variety highly selected for yield and other desired traits so that genetic variability between individual plants is minimized. All too often the selection process that produces the new varieties emphasizes yield characters and ignores or minimizes resistance to pests. Even where pests are considered in the selection process, it is not possible to expose the new selections to all possible pests (or all strains of any one pest). In some cases, clonal propagation exaggerates this situation (e.g., tea, potatoes). Coupled with the introduction of the new high-yielding varieties are a variety of new management practices which enhance the high-yielding characteristics of the plants but also at the same time often enhance their susceptibility to disease or attack by insects. Fertilization produces larger and more succulent plants that are more susceptible to pests than plants grown at lower nutritional levels. For example, damage to rice plants by stem borer larvae is heavier in paddy fields which receive higher rates of nitrogenous fertilizers (Ishii and Hirano 1959); the larvae grown on such plants are bigger, the adult females lay more eggs, and the plants would appear to be more attractive for oviposition. The same would appear to be true for the rice gall midge. Irrigation particularly when managed so that a uniform moisture supply is available to the plant also favours certain diseases and insect pests.

The new high-yielding plant varieties of the Green Revolution require reliable water management and increased use of fertilizers to express their yield potential. The combination of water, fertilizer and new plant variety produces a different micro-environment and a different plant environment in the rice paddys and other grain fields. As a result the plant protection problems in these modified agroeco-systems have changed. For example, in rice, populations of planthoppers and leafhoppers

have increased in importance as pests and the virus diseases which these insects transmit have increased to serious proportions (e.g., witness the serious outbreak this year of tungro virus in the Philippines). Rice gall midge has increased in parts of Indonesia, India and Ceylon and the rice stem borer species complex has changed in several areas. The paddy leafroller, *Marasmia bilinealis*, in Ceylon formerly mainly a pest in shaded areas, has assumed a new significance correlated with the higher use of fertilizer and the new rice varieties. In general, rice leaf blight has become more important and rice blast less important.

The complicated changes that resulted in the Chia-nan area of Taiwan when the Wu-Shan-Tau reservior was built about 1960 illustrate in more detail these changes and how rapid this agroecosystem evolution can come about. The new irrigation water impounded by the reservoir made possible a greater intensification of agriculture in the Chia-nan area which was formerly limited by the availability of water particularly in the non-monsoon periods of the year. There were changes made in the rice varieties and a great reduction of the number of varieties grown. Previously, the first crop was almost entirely *japonica* type rice and the second crop about 50% *japonica* and 50% *indica*. Now both crops are essentially all *japonica* and 60% of the acreage is devoted to the single variety Tainan 5. With this varietal simplification, it is quite significant that the variety Tainan 5 while somewhat resistant to rice stem borer and rice blast is quite susceptible to planthoppers and sheath blight.

In the new agricultural scheme in the Chia-nan area, at transplanting time the plants were set out closer together (15 cm in the rows, 20 cm between rows compared to the 25 x 25 pattern formerly used). The reliable availability of water made possible the consistent production of two crops of rice each year and an alteration in the planting and harvest times. Under the old system in the Chia-nan area, the first crop of rice was planted in February and March and harvested in June and July; and the second crop of rice was planted in July and August and harvested in October and November. In the following year, they went to dry-land crops such as tobacco, sweet potatoes, mustard greens and cabbage. With the more reliable water, they had two crops of rice each year, the first starting in December or January and the second in June and July. In addition, they were able to add a third winter catch crop of vegetables especially if they started this before the second crop of rice was harvested.

This intensification of agriculture with multiple cropping required increase use of fertilizer. Previously in this area they had used only manure and rice straw compost but under the new system they applied high levels of commercial fertilizers to the fields.

The Chia-nan farmers were organized into plant protection teams for community pest control and the use of pesticides greatly increased. These cooperative rice pest control teams were organized to provide unified and cooperative operation to combat disease and insect pests. The activities of these teams were tied to a surveillance and prediction system and were thus able to provide better timing of applications and better choice of insecticides. Also it permitted a channeling of technical guidance from the district demonstration field stations to the farmer teams through short training courses, discussion panels and direct contact of the extension workers with the plant protection team leaders.

With all of these changes in the rice agroecosystems the pest complex changed significantly as might be expected. The rice hispa, *Hispa armigera,* and rice leaf beetle, *Oulema oryzae,* which formerly were major pests were essentially eliminated through the use of insecticides. The yellow rice borer, *Tryporyza incertulus,* decreased in importance because of a combination of partially-resistant rice varieties, insecticidal control, and better land management. With irrigation, it was easier to plow fields at the right time, hence, harder for *Tryporyza* to overwinter. At the same time, presumably because of multiple cropping and high use of fertilizer, the striped rice borer, *Chilo suppressalis,* increased in importance. Leafhoppers (*Nephoteitix* spp.) and planthoppers (*Sogatella* and *Nilaparvata*) were greatly favored by the new microhabitat in the rice paddys particularly as a result of the new plant type, closer spacing and fertilizer use. As a result their feeding has caused severe damage but more importantly they are vectors of viruses and mycoplasma. Yellow dwarf, tungro virus, and a new disease called transitory yellows are especially important. At the same time, rice blast was declining in importance through the development of varieties with moderate to high resistance and the use of fungicides. Finally, sheath blight of rice caused by *Thantephorus cucumeris* was increasing in importance and none of the rice varieties in Taiwan possess adequate resistance to this disease.

The rice varieties in Taiwan are mainly *japonica* varieties developed in Taiwan. In other parts of Asia, similar patterns were evolving with the introduction of the new high yielding *indica* varieties developed by the International Rice Research Institute and others.

Attack by insects and disease are not new in man's agriculture. In fact, they have been challenging his crop plants for thousands of years. Over these many years, in man's fields a selection with essentially no control by man occurred for plant types which were highly heterozygous and heterogeneous with enhanced adaptability to the environment including resistance to a wide array of pests. Furthermore, the tillage and fertilizer practices of many traditional agricultures built-up over the ages usually were so poor that they produced plants of a type not as susceptible at least to some pests as others grown under conditions of good tillage, high fertilization and adequate water supply. The Green Revolution in its various forms has changed this traditional pattern. Where previously the farmers were growing many kinds of traditional varieties under rather poor growing conditions (e.g., in Indonesia there are more than 600 Bula rice varieties; these are the traditional varieties of rice of that country), now where the Green Revolution has taken place, they are growing just a few varieties with high levels of fertilizer. In other words, the Green Revolution is producing a special type of monoculture. Huge acreages (perhaps in the future covering a continent) devoted to a single genetic type of plant with rather good growing conditions (Adams, Ellinghoe, and Adams 1971).

In terms of our total agricultural history, our experience with monocultures is exceedingly short. The significance of the risk is underscored by the 1970 epiphytotic of the Southern Corn Leaf Blight in the United States. It was estimated that 90% of the U.S. corn acreage in 1970 was planted in varieties having a common source of cytoplasm. As a reaction to this huge loss, in 1971 corn belt farmers were encouraged to plant 12% more acreage. Some adjustment was made away from leaf

blight susceptible varieties but more important the dry summer was favourable for corn and unfavourable for the Southern Corn Leaf Blight. The result is a record breaking crop of 5.5 million bushes—a problem of a different kind. The new Mexican wheat varieties planted so widely through Asia from Turkey to India involve a relatively small range of genotypes. A shift in the spectrum of races of wheat rust in any of these countries could be disastrus. Or a new pest originating some obscure plant could do the same thing. It is true that these new varieties have certain kinds of resistance not found in traditional varieties but the traditional varieties were not grown over such large areas. I should add that to critics of the Green Revolution Borlaug retorts 'it is far better for mankind to be struggling with new problems caused by abundance rather than with the old problem of famine'.

My statements above identify a risk that exists in the Green Revolution. It is not an argument against the development and distribution of the new grain varieties but rather an argument for the development of sound plant protection systems to secure the gains achieved thus far in the Green Revolution and the gains we can expect in the future. We must be careful not to fumble the ball at this point in the game.

The agroecosystem is more than the relationships among the crop plants and their conditioning environment. It also included the associated agricultural, industrial, recreational and social activities of man. Whatever plant protection system is utilized it also becomes a part of the agroecosystem. Furthermore, the pest control system must be accommodated to the fundamental framework of the local society. This is especially clear in the several countries of South and Southeast Asia. The habits, customs, and traditions ingrained in these cultures over centuries are not easily accommodated in typical North American plant protection systems. The structure of land tenure, religious beliefs, pricing and marketing systems, and educational institutions can sustain the operation of a pest control effort, hinder it, or prevent it entirely.

Returning to the specifics of the new rice agroecosystems produced by the Green Revolution in Southeast Asia, there are some other implications of considerable interest to plant protection. The farmer with triple or more his former yield is no longer a subsistence farmer and he has some cash income. For example, the farmers in India and Pakistan cultivating the new Mexican dwarf wheat varieties under the recommended management practices have increased their net income from 37 dollars per hectare with the local varieties to 162 dollars with the dwarf Mexican varieties. The farmer can now make purchases he could not consider formerly and his standard of living is raised. Perhaps, this may result in a better balanced diet for his family or more likely a sewing machine appears or a bicycle, motor scooter, or a transistor radio. At the same time, he can make decisions and take actions with respect to his crop that may require capital outlay, e.g., fertilizer and pesticide purchases. This greater freedom of choice also involves certain new risks. The expanded use of pesticides if not developed carefully can itself lead to greatly aggravated crop protection problems such as the more affluent growers in North America have encountered in their pest control (Newsom 1970).

In some countries of Southeast Asia, developing industries have been a source of employment for farm labour and as a result incomes to farm families have been significantly augmented. However, this utilization of farm labour coupled with the increased labour demands of multiple cropping has created labour shortages at critical times in some areas. This also has impact on crop protection especially for weed control which depends so heavily on hand labour in the tropical areas.

The New Philosophy of Pest Control

At the same time that the Green Revolution has been forcing the importance of plant protection to the forefront, a new approach to plant protection has been developing in countries scattered all over the world. Plant protection specialists (in particular entomologists) have come to realize that the over-dependence (in some cases complete dependence) on pesticides such as developed in many countries after World War II is fraught with serious handicaps. In the developing countries of the world and in particular those of Southeast Asia there are many examples of these handicaps (or as I called them earlier in this talk unfavourable consequences) of over-dependence on pesticides for pest control. There are also examples from Southeast Asia which can be cited among the best examples of integrated control that we have available.

First, let us look at some of the unfavourable aspects as they have developed in Southeast Asia.

Residues : In general, there has only been in very recent times a concern in Southeast Asia the hazards of pesticide residues on food crops. Very few laboratories exist in the area which can monitor the levels of pesticides in food products. Residues are now being given some attention but it should be remembered that the level of pesticide use in this area (with the exception of certain vegetables) is far below that of Japan, Europe and North America. In all of Southeast Asia, according to FAO statistics (for 1967) there is less than 1.2 million pounds of insecticides of all types used in agriculture. However special problems of residues in Southeast Asia have arisen where meats, tobacco and other products are shipped in international trade.

Resistance : As would be expected, resistance to insecticides has developed where the insecticide use has been most intensive. In most cases the documentation of the cases leaves much to be desired and most of the evidence is circumstantial. The greatest trouble with resistance has been encountered with the diamond back moth, *Plutella maculipennis,* on a variety of cruciferous crops. A number of chemicals are no longer effective against this pest. In one area, they are now using mevinphos every two or three days on watercress (this totals about 20 applications during the season of this rapidly growing crop). Rice stem borers and brown planthoppers in rice have also developed some resistant populations where insecticide use levels have been high.

Unleashed Secondary Pests : Another consequence of pesticide use has been the common occurrence of pest outbreaks by species that previously were innocuous or of minor pest status. The examples of this type of pest in cotton in many parts of the world have been well documented (Adkisson 1969; FAO 1968, 1970; Smith 1969; Smith and Reynolds 1971; van den Bosch *et al.* 1971; Wille 1951).

A detailed and documented case of unleashed secondary pests from the Asian area is provided by insects of tea in Ceylon (Danthanarayana 1967). Tea was first planted in Ceylon in 1867, following the threatened extinction of the coffee plantations by rust. By 1900, there were about 300,000 acres of tea and now the acreage of tea is about twice that level (Cranham 1966). One of the main pests in the early days was the tea tortrix, *Homona coffearia,* a leaf-eating web-spinning caterpillar which had moved over from coffee. This persisted as an intermittent pest of tea in Ceylon until 1935 when a braconid parasite, *Macrocentrus homonae,* was introduced from Java (Cranham 1961a). This gave excellent control and the tea tortrix from that time was essentially a non-pest until 1962.

A shot-hole borer, *Xyleborus fornicatus,* which has presumably moved over from native vegetation has been a serious problem virtually throughout the history of tea growing in Ceylon. This pest bores into the woody tissues, weakens the young branches so that they are easily broken and provides access for rots in the plant frames. Prior to 1960, research and control attempts emphasized cultural and agronomic manipulations, particularly pruning systems.

Several species of leaf-eating caterpillars of various species were occasionally a problem during this period but no action was taken and outbreaks declined naturally. The existence of natural balances for these caterpillars was well appreciated and was considered to be the main force in keeping several potential pests in check. Such outbreaks as did occur, were explained as localized temporary break downs in this natural balance, and the restoration of the normal situation was considered to be the subsequent increase of natural enemies (Gadd 1941).

In 1961 dieldrin (at 1.5 lb/acre sprayed on the pruned frames) was introduced for shot-hole borer control (Cranham 1961b). The importance of natural control in tea plantations and the possibility of side effects from dieldrin was recognized (Baptist 1956) but shot-hole borer was such an important and difficult pest that the dieldrin was recommended and used. Tea tortrix outbreaks began almost immediately because of the effect on its main parasite, *Macrocentrus homonae.* As the acreage receiving dieldrin treatment increased two other pests appeared, the twig caterpillar, *Ectropis bhurmitra,* and the looper caterpillar, *Buzura strigaria.* These three pests completely defoliated large acreages of tea (Danthanarayana and Kathiravetpillai 1970), and DDT was used to combat these induced pest outbreaks. Prior to these outbreaks, damage from the twig caterpillar in Ceylon was very minor and the looper caterpillar had never been recorded previously as a pest. In addition, unusual outbreaks of several previously innocuous lepidopterous insects occurred in localized areas where there had been dieldrin spraying. Among these were outbreaks of bagworms (*Manatha albipes*), faggot worms (*Clania cramerii*), red slug caterpillars (*Eterusia aedea*), armyworms (*Spodoptera litura*), and cutworms (*Agrotis segetum*).

The picture was one of increasing acreage sprayed with dieldrin followed by increased acreage sprayed with DDT to cambat the induced outbreaks of caterpillars. In 1960, 1,145 acres were sprayed with dieldrin and 551 acres (about half) then had tea tortrix outbreaks. By 1965, 15,606 acres received dieldrin and about two-thirds of these (10,366 acres) needed DDT. In 1960, no outbreaks of either twig caterpillar or looper caterpillar were recorded; but in 1966 there were 28 recorded outbreaks of twig caterpillar and 10 outbreaks of looper caterpillar. When DDT was used for control of caterpillars, it also brought about red spider mite (*Oligonychus coffeae*) and scarlet mite (*Brevipalpus californicus*) outbreaks at least in the drier areas (Cranham 1966).

Because of all these difficulties, the use of dieldrin was eliminated at the end of 1966 and the natural control was gradually restored. Outbreaks of these unleashed pests dropped sharply; in 1968 there were only two mild outbreaks of the twig caterpillar and none of the looper. In fact, by 1969 twig caterpillar populations became so low that ecological studies of this unleashed pest had to be discontinued for lack of study populations.

For the last three years, heptachlor has been substituted for dieldrin and spray applications are only applied to blocks having high shot-hole borer infestations. Secondary outbreaks have been minimized under this supervised control scheme utilizing a high treatment threshold level (60% of small stems infested).

Another example of what would appear to be an example of an unleashed secondary outbreak occurred in rice fields in Java. The Government of Indonesia has been attempting intensive rice production in several large demonstration areas under what is known locally as the BIMAS* program. This unleashed outbreaks of the rice gall midge, *Pachydiplosis oryzae*. Infestations of the rice gall midge occur at subeconomic levels in most rice fields in Java. Outbreaks at economic levels have occurred only occasionally in the past. However, when large acreages in the BIMAS areas were sprayed with phosphamidon for rice stem borers, a severe outbreak of the rice gall midge occurred. The evidence that this was an example of a pest unleashed by pesticide use is only circumstantial.

There are also several examples of pests attacking plantation crops in Malaysia which have been handled most effectively with the integrated control approach (Conway 1971; Conway and Wood 1964; Ho 1971; Wood 1968, 1969, 1971; Wood and Nesbit 1969). In the late nineteen-fifties and early sixties, some very severe outbreaks began to occur of bagworms (Psychidae) and nettle caterpillars (Cochlidiidae) on oil plams. Previously these had not been considered to be of any great importance. Severe defoliation took place and extensive spray treatments over large acreages were required to keep the pests in check. Studies of the situation soon showed that the worst outbreaks had come after the initial use of broad-spectrum insecticides (DDT, dieldrin and endrin) applied against other less serious pests. The more insecticide was used, the worse the problem became. It was soon established that parasites and predators of these two lepidopterous pests are very important in natural regulation. Spraying of the broad-spectrum materials was stopped to permit the re-establishment of natural enemy activity and many of the outbreaks subsided. In some plantations or portions of plantations apparently the synchronization of parasites and pest caterpillairs had been disrupted and cycles of outbreaks continued to occur at economic levels. The short residual organophosphate trichlorphon was used to depress these continuing outbreaks (incidentally, these occurred in the formerly treated areas). Gradually there was a decline in the frequency of outbreaks so that in recent years very few spray treatments have been needed.

Equally dramatic were events in cocoa in Sabah (Conway 1971). Estate-scale planting of cocoa on the east coast of Sabah commenced in 1956 and soon assumed significant economic importance. The cocoa is mainly planted in clearings in the primary forest, often with selected saplings and understory trees left to provide the necessary shade. Borer attack especially of a caterpillar ring bark borer, *Endoclita hosei,* leads to die-back and death of the cocoa trees. Faced with this situation, growers found that dieldrin sprays gave some control of the problem initially. After their use, leaf-eating caterpillars became troublesome which led to more spraying with a whole range of non-selective insecticides. This was followed by more pests of various groups, in outbreaks of increasing intensity until eventually very severe defoliation by several bagworms was experienced. Conway, appreciating the probable ecological factors involved, recommended that spraying be stopped. This was done, and some of the pests began to decline more or less rapidly, with obvious parasite activity involved. Bagworms remained and a program of trichlorphon spraying was pursued until they too decline to insignificance. In the meantime, investigations showed that a particular common species of shade tree, *Trema cannabina,* was also host to the original bark borer pest. Although lethal to the cocoa trees, the pest was relatively harmless to the shade tree, and hence it served as a source of continued attack until removed.

*Bimbingan Massal Swa Sembada Bahan Makanan= Massive guidance to become self-supporting in food.

The Special Opportunity for Integrated Control Approach in Tropical and Subtropical Areas

There is without question a special opportunity to develop the broad ecological approach to pest control in the less developed countries in the tropical and subtropical areas of the world. In these regions, the physical environment is in general conducive to population increase of insects and disease pathogens throughout the year especially when the contrast with temperate environments is made (Doutt and DeBach 1964). As the result of evolution over eons, the biotic elements of population regulations have developed and have become dominant in regulation in tropical and subtropical areas. This is demonstrated by well-established biotic controls on a number of pests and potential pests of tropical crops, e.g., coconut, citrus, tea, rubber, oil palm, and cotton. This 'hidden natural control' is most often revealed when we disrupt it by introducing a chemical pesticide into the agroecosystem (Wood, 1971). This hidden natural control which keeps innumerable potential pests from becoming pests is a valuable resource which should be conserved.

It is clear that not all the important crop pests have adequate biotic controls, e.g., rice pests, cabbage pests, as they are now handled in modern agroecosystems. However, even with these pests we may have biotic agents which give partial controls. The task of the plant protection specialists is to conserve and protect these hidden natural controls and partial control agents and mold them with other controls (resistant plant varieties, chemical controls, cultural controls) into a sound economic protection system. This is another way of describing the integrated control approach.

Another aspect which favors integrated control development in tropical and subtropical areas is that with a few exceptions, the agroecosystem of these areas have not been subjected to such intensive application of chemical pesticides as is the case with those of some temperate areas. In the developing countries, the control system, can develop from a relatively undisturbed base; while in many temperate agroecosystems e.g., cotton, deciduous fruits, the situation is so upset through the continued high level use of pesticides that it normally takes several years to re-establish the biotic control agents.

Relevance of Green Revolution to Plant Protection in the United States

What does the preceding discussion of plant protection in the less developed countries mean to us in the United States? Firstly, it defines a role that we should have, and with it significant responsibility, in international plant protection. Actually we entomologists are significantly involved and we have great responsibilities in international plant protection. We are involved in many ways. A significant number of our* ESA members are directly involved in plant protection projects in the less developed countries. Many of us are involved in the training of students from these countries. We are also involved when we correspond with our professional colleagues overseas, or ship them a chemical pesticide, or send them a reprint or book. That, in brief, describes our high level of involvement in international plant protection, but what is our responsibility here? In my opinion it is

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* The Entomological Society of America.

our moral responsibility at every level of involvement in international plant protection to assist in the development of plant protection systems that are appropriate to the local environment, economy, and social customs. These plant protection systems should have the long term view in the solution of problems. Furthermore, this long term approach strongly suggests that the system be firmly based in ecology and that it depend on manifold control techniques. It also strongly suggests that our emissaries in the developing countries of the world should not be castoffs from our pest control technology whether they be men, chemicals or whatever.

In my stressing of manifold control techniques in plant protection systems for agriculture in the tropics and subtropics, I wish to make it very clear that this does not mean the substitution of biological controls for all chemical controls. It is true that I strongly advocate a greatly increased interest in and support for biological control and other neglected controls appropriate to the better management of pest populations, but this does not even infer the elimination of chemical controls. That, of course, would be inane because it does not take into account the facts of the real world.

In many difficult-to-manage agroecosystems, for example the one that centers around rice paddy, it is unrealistic to believe that biological control can achieve satisfactory control of all the insect pests or perhaps not even one of the major key pests throughout all of its distribution. However, biological controls (I am using biological control in its classical meaning i.e., the use of parasites, predators and pathogens) coupled with other control techniques has the potential to provide satisfactory pest management on a stable, realistic and economic basis. I believe the role of biological control of rice pests has been neglected. Most rice research workers would appear to consider biological control of limited importance for rice pests. Actually the potential value of natural enemies of rice pests is still unknown. What is needed is a complete and careful analysis of existing mortality factors existing in rice agroecosystems of Southeast Asia. This should be more than a mere cataloging of parasites, predators and other kinds of mortality factors. It should be an analysis of how, when, and where they are effective and ineffective in regulating pest species (DeBach and Huffaker 1971; Nishida and Torii 1970). This can then be pursued by the study of ways that these natural mortality factors can be augmented and supplemented. Moreover, the ways in which natural enemies can be augmented is not limited to the introduction of new species from other areas. Periodic release of insectary maintained cultures is sometimes useful. In other cases, providing alternate hosts or in other ways supplementing the food supply can be used (Hagan, Sawall and Tassan 1971; Parker 1971). Selective use of pesticides can assist a natural enemy which by itself is only partially effective, so that the combination results in satisfactory control (Smith 1970).

There is a second way in which these tales of Southeast Asia relate to our own problems in the United States. In the examples, I have provided this morning and others from the area is another large body of evidence supporting the thesis that we cannot in the long run (and often not in the short run) provide adequate pest control with chemicals alone. It shows that pest control, or better pest management, must be founded on an ecological analysis of the pertinent agroecosystem and developed through the utilization of a manifold variety of control techniques. Over the pest

decade it has been clearly demonstrated that the integrated control philosophy is a sound, practical and economical approach to plant protection. The following list of examples from all over the world is only a partial listing of the varied examples: cotton in Peru, California and Texas (Adkisson 1969, FAO 1968, 1970; Smith and Reynolds 1971; van den Bosch *et al.* 1971); apples in Washington, Canada and Germany (Hoyt 1969; Hoyt and Caltagirone 1971; MacLellan 1963; MacPhee and MacLellan 1971; Madsen 1968; Madsen and Morgan 1970; Steiner and Baggiolini, 1968); peanuts and sorghum in Texas (Bottrell and Cate, 1970; J. W. Smith, 1971); coconuts, oil palm and cocoa in Malaysia (Conway 1971; Wood 1968, 1969, 1970, 1971; Wood and Nesbit 1969); strawberries, peaches, alfalfa and grapes in California (Doutt, 1965; Hagen, van den Bosch and Dahlsten, 1971; Hoyt and Caltagirone 1971; Stern *et al.* 1959); tobacco in North Carolina (Lawson *et al.* 1961; Rabb 1971; Rabb *et al.* 1964); cabbage in Missouri (Parker 1971; Parker, Lawson and Pinnell 1971); citrus and olives in California and Israel (DeBach, Rosen and Kennett 1971; Harpaz and Rosen 1971); and in glass-houses in England and the Netherlands (Hussey and Bravenboer 1971).

In closing, I am reminded of a definition of integrated control one of our ESA members from the San Joaquin Valley gave us a few years ago (Hansbery 1968). He prefaced the definition by suggesting that integrated control was not new and said, '.. integrated control is just good entomology'. My introductory remarks this morning certainly support the concept that the integrated control approach is not new. As to equating integrated control with 'good entomology,' I am happy to do just that and I would only add that as responsible economic entomologists we cannot afford again to let this 'good entomology' escape us as we did in the 1950s when 'the new,' 'the good,' and 'the great' insecticides overwhelmed us and took possession of economic entomology. If we let 'good entomology' escape us again the ghosts of Forbes, Walsh and Woodworth will come back to haunt us.

As we seek this good entomology we should be less concerned with—Who is for DDT? Who is against insecticides? Who is for biological control? Who is against biological control? Who will get the credit? and be more concerned with how we are going to implement at the practical level for the farmer an ecologically and economically sound program of plant protection.

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