New Developments and Problems in the Use of Pesticides

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Pest Control in Relation to Human Society

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Man did not arrive at his present situation on this planet without a struggle. He had to use every ounce of muscle, nerve, and brain to overcome the obstacles along the way. The thin thread of civilization could have been snapped by any one of hundreds of natural catastrophes had he not shifted the forces of nature to serve his purposes and accommodate his ever-growing ambitions.

The battle against his environment and the other forms of life therein were no more important than the struggle against his own temerity and refractoriness to change, which could deprive him of the benefits of his own resourcefulness. He has constantly had to fight the indecision and retrogressive forces born of his own superstition, ignorance, and blind, unreasoning fear. It has always been thus; it is so today.

The first man who sought to understand fire and put it to use in serving man's comfort undoubtedly suffered much more than the inevitable burn on his fingers. He was probably classified as an agent of the devil and banished from the roving tribe until someone discovered that he lived better and more securely than they. The same forces of ignorance and fear did their best to deprive us of better health through vaccination against virulent disease agents. Even today they deny youth in some of our major cities their natural birthright of sound teeth by refusing to make available to them the nominal requirement of fluorine in their drinking water. A disgraceful battle was waged against tuberculin testing of dairy herds to protect the children of mankind against needless exposure to the great white plague. The same forces are marshalled today against a new servant of mankind—the pesticides to be used in protecting and expanding our food supplies. Every step forward, it seems, has to be won by resolute force under the banner of progress.

The only thing common to each of these several examples is that they would not have been made necessary had man not multiplied to such an extent that he overtaxed his environment. The counter-forces raised against them were born of the same innate fear and suspicion of all things new and the unknown in our world. This fear rises up whenever man encounters something invisible that he cannot lay his hands on and enter into mortal combat with face-to-face.

There is a tremendous cry about the use of pesticides in food production but only nominal concern over the destruction of human life by automobiles. Yet the respective hazards to human existence in 1956, a typical year, were in a ratio of 58 to 36,972. There is no evidence of fatalities from consumption of poisoned food, of malignancies induced by the chemicals, or of vicious death on the farm even nearly comparable to that caused by the cornpicker which remains the most gruesome source of farm accidents. Reams of statistics such as these mean nothing in the face of man's great fear. It is necessary, therefore, to examine every facet of the use of chemicals in food production to see if they are absolutely necessary or could be dispensed with. Only then can we argue that the great hidden fear must be ignored in the name of progress. The potential value of pesticides can be appraised from many viewpoints but for purposes of this discussion we might consider their relation to: human necessity for farm produce, the efficiency of farm labor, maximum utilization of natural resources, maintenance of balance between supply and demand, and the fringe benefits to society.

Necessity for Productivity

Very little of the world's surface is serviceable to mankind. About 90 per cent of the people live on 13 per cent of the land area. For the most part, we are restricted by climate and terrain to the fringe areas around the great land masses next to the shorelines. According to the Food and Agricultural Organization of the United Nations, a fraction over 10 per cent of the land mass is arable. The United States is fortunate in that the cyclonic storms from the Gulf of Mexico deposit water on the great inland valley of the Central States and make it into a fertile plain. Even so, we cultivate only 380,000,000 of the 1,904,000,000 acres available to us.

The charge is often made that the United States could forego the use of pesticides since the agricultural establishment is producing more than is required. The outcries against surpluses are based on disruption of agricultural economy rather than wasteful production. They do have a disastrously depressing effect on the market prices of commodities but the current over-production is little more than a safe operational margin.

It would be possible to alleviate all surpluses of any crop staple by permitting any one of several pests to operate unrestricted for a couple of years. A good example is the black stem rust of wheat, controlled primarily by breeding resistant varieties. In 1935 a new race of rust that had appeared some years previously ran wild on the variety Ceres and caused losses aggregating some 160,000,000 bushels of wheat. It is interesting to note that two years of such catastrophic damage would eliminate the wheat surplus problem in the United States.

New varieties were bred and Ceres disappeared from the farms. But, as pointed out by Stakman and Harrar, this fungus has been controlled adequately by using resistant varieties in no more than 20 of the past 50 years. A new race (15B) appeared in 1950 and began to attack the durum wheats. By 1954 it was causing 25 per cent loss in some states and the crop was not worth harvesting on many farms. The acreage declined from 2,103,000 in 1951 to 1,658,000 in 1953, and to 1,112,000 acres in 1954.

The New York *Times* (March 19, 1954) describes what was happening very well: "The growers are tiring of their losing battle with black stem rust. . . . A normal yield of durum formerly was about 35,000,000 bushels. In 1952 production dropped to 22,000,000 bushels and in 1953 to 14,000,000. Last year the yield was only 5,500,000 bushels and a large part of that was of poor quality.

"The sharp drop in supplies of durum has caused the market to skyrocket. It has sold this season as high as $4.65 a bushel. At present the price is $4 a bushel or nearly double that of ordinary wheat. Even at that price little is available. Most macaroni growers are using a mixture of 25 per cent durum flour and 75 per cent flour from softer wheats."

Who paid the price of this natural catastrophe? The farmers who were driven out of business, the macaroni producers who sold a second-rate product, and, most of all, the consumer suffered because there was no chemical to protect a vital crop.

Agricultural production in the United States today cannot be considered apart from world-wide needs and our own future requirements. Currently, our people have an average daily supply of 3,200 calories and 96 grams of protein. This is well above the minimum acceptable standard of 2,400 to 2,700 calories and 65 grams of protein. It is disturbingly high in view of the average caloric intake of 2,100 and 56 grams of protein in the Far East. These people are being slowly starved to death.

There is a great hunger belt in the world that extends over three continents. It is roughly bounded on the north by a line drawn through northern Mongolia, the Straits of Gibraltar, and the southern tip of Mexico. The southern boundary extends from Borneo through Rhodesia to Uruguay. Unfortunately, the people in this world-wide belt are not making satisfactory progress in solving their food problem. In 1961 the world population stood at 133 per cent of the pre-war level and food productivity at 155 per cent, so some progress has been realized. However, this has been inequitably distributed. There was a 68 per cent increase in food and 42 per cent increase in the population of the United States; 43 per cent and 20 per cent, respectively, in western Europe as compared to 60 per cent and 68 per cent in Latin America, 50 per cent and 51 per cent in Africa, and 48 per cent and 54 per cent in Oceania.

In order to overcome the world-wide deficit, there is need for 1.8 million metric tons of animal proteins as milk solids, 0.4 million metric tons of pulse crops as dry beans and peas, 35.6 million metric tons of other proteins as wheat, and an additional 8.6 million metric tons of wheat for calories. The crying deficiency is in proteins. To correct the over-all deficiency in terms of U. S. production would require 35 per cent of our milk production, 40 per cent of our dry beans and peas, and 120 per cent of our wheat. There are no food surpluses in the world today. There is only maldistribution and poor allocation of what is available.

The United States has a responsibility as the citadel of human freedoms to free these people from hunger. If there is any overproduction of food in the United States it should be accepted by us with gratitude and we should seek means for distributing it where it will do the most good in preservation of human freedom. These freedoms will not long endure for any of us unless we can extend the benefits of our system to others before they strike out in blind agony against all law and order. Our problem is not to curb food production here but to find the means of increasing it in the great hunger belt.

What will be the needs of this nation a decade from now? By 1975 we can expect to have a population of about 210,000,000 people since our net rate of increase is approximately three million persons per year. To supply these people adequately we need to add productivity equivalent to about six million acres a year. There simply are not to be found some 60 million acres each decade since we probably could not reclaim more than 15 million acres by drainage and extension of irrigation. The only possibility is to increase the productivity per acre.

There are many means of increasing productivity: improved soil fertility, seeding of better varieties, more intensive cultivation, dual cropping, irrigation, etc. However, in any planning for the future the tremendous damage from crop pests looms large. According to the careful survey made by the U. S. D. A. in 1954, the losses in the United States from insects, diseases, and weeds probably average about 21 per cent of the potential production. This is equivalent to losing 88 million of the 358 million acres before they could be harvested. Unfortunately, the losses are not distributed so that they can be disposed of so easily. The inadequate crop has to be harvested, so the farmer loses much of the labor, fertilizer, and equipment expenses he has invested. Any benefits he might have expected from use of extra fertilizers, cultivation, or other beneficial practices have automatically been depreciated by the pests. It stands to reason that improvement in the control of pests is the first step toward greater productivity. It is the most direct pathway to realization of all the gains from other production devices.

There is little need to dwell on the value of pesticides for increasing the yields per acre. The literature is replete with references to the detailed benefits derived from insecticides, fungicides, herbicides, and nematocides. The yield increase following application ranges from nothing to complete crop salvage. It is next to impossible to measure these benefits precisely because the results are confounded by many uncontrolled environmental forces, direct effects of the chemical on plants, and even the density of crop stand and supply of available soil nutrients at the time of application. Undoubtedly, the benefits are sometimes over-estimated by participating scientists who, in all sincerity and honesty, are impressed by the extreme benefit rather than the average sustained improvement. However, there is plenty of evidence of under-estimation of the potential value of pesticides by the biologists who use them, as illustrated by the history of potato protection in the United States.

The potato is subject to attack by at least 200 insect and disease agents capable of impairing growth and yield. The late blight caused by the fungus *Phytophthora infestans* and the potato leafhopper are two of these. After Bordeaux mixture was perfected for controlling blight it was found to increase yields even in blight-free years. Both plant pathologists and entomologists under-estimated the beneficial effects from repelling leafhoppers. It is doubtful whether these biologists had a sound appreciation of how much damage these little leaf-sucking pests were doing. It was not until 1945 when organic pesticides were introduced for use on potatoes, with DDT giving almost perfect control of leafhoppers and Nabam replacing Bordeaux for blight control on much of the acreage, that the truth became evident. Bordeaux mixture actually had been depressing growth somewhat but had given sufficient ancillary benefits in repelling leafhoppers so that it seemed to stimulate plant development. In the nine years after the introduction of the DDT-Nabam team, the average yield of potatoes per acre increased 90 per cent. The statistics on potato production in the 50-year period since 1901 are presented in Table 1.

TABLE 1. POTATO PRODUCTION IN THE UNITED STATES, 1900–1950

Period of record	Acreage harvested	Yield per acre (bu.)
1901–1905	3,115,000	91.8
1911–1915	3,473,000	100.6
1921–1925	3,359,000	106.5
1931–1935	3,510,000	107.6
1941–1945	2,818,000	140.9
1945	2,700,000	155.1
1946	2,598,000	186.3
1947	2,101,000	185.2
1948	2,109,000	215.5
1950	1,690,000	253.4

This record shows that we provided the American public with approximately 50 per cent more potatoes from 45 per cent less acreage in 1950 than in 1901. The great gains of 20 per cent per acre during World War II (1941-1945) came from putting into practice the knowledge gained concerning use of fertilizers, improved varieties, and irrigation, as well as more extensive use of pesticides. However, the gains of 1945-1950 were primarily a triumph of the two new pesticides. One should not claim that these pesticides increased the average yield from 140.9 bushels per acre to 253.4 bushels, because the result was confounded by retirement of 1,128,000 acres. This permitted potato culture to be concentrated in the better-adapted areas. However, the pesticides can be credited with the major role *in making it possible to increase yields by 112.5 bushels* per acre and releasing acreage for other purposes to which it would be better adapted. A careful study of yield changes in other crops, such as wheat or sweet potatoes, where pesticides are not in such essential demand, fails to reveal a comparable increase in the post-war period, so one is forced to accept the data of Table 1 as evidence of the impact of the new pesticides on this crop.

Comparable statistics on several other crops have been compiled by Decker (*Agricultural Chemicals*, February 1954) on the changes in average yield per acre in the United States in the five years following the introduction of DDT. Those field crops requiring extensive use of insecticides experienced increases of 6.74 to 20.13 per cent, vegetables 11.88 to 61.75 per cent, and seed yields of legume 10.72 to 42.19 per cent. In contrast, those crops requiring scant or no treatment with insecticides experienced yield increases of −4.96 to 6.02 in field crops and −3.25 to 6.41 in vegetables. The correlations are so obvious that they cannot be ignored, even though the data may be confounded by many other factors. When taken in conjunction with data from thousands of meticulously conducted field trials comparing treated and untreated plots, they constitute overwhelming evidence that pesticides have led the progress in agriculture in the post-war period so that food production by 1961 stood at 168 per cent of the pre-war level.

Efficiency of Farm Labor

The greatness of the United States is derived in no small measure from the strength of its agriculture. Ever since 1860 we have applied the best of scientific skill and mechanical knowledge to solving agricultural problems. We have succeeded in releasing manpower from the grinding routine of producing food and fiber so that its energies can be diverted to other pursuits in industry, science, the arts, and commerce. The great upsurge of industry in our country did not occur spontaneously and by chance. We moved forward at an unbelievable rate in world affairs only because we could feed our people so well with so small a commitment of manpower.

The agricultural economy of the United States in 1962 has little resemblance to that of 50 years ago. The changes are somewhat in the same order as those in automobile manufacturing when one compares a modern assembly-line operation with the village blacksmith or local carriage maker undertaking the new operation of making cars at the turn of the century.

A few statistics on the state of health in our national economy may serve to orient our thinking. The data in Table 2 were compiled by economists at Purdue University for the changes occurring since World War I and projected for the next decade. We have made great progress and we can look forward to further improvement by 1975.

Farm output has increased in proportion to population and is expected to maintain or improve this ratio during the present and next decade. The most significant fact in these statistics is that the increased productivity of farms has been achieved with a constantly

TABLE 2. PRODUCTION RECORDS FOR INDUSTRY AND AGRICULTURE IN THE UNITED STATES FOR 1920 AND 1955, AND ESTIMATES FOR 1975

Factor under observation	Status in year		
	1920	1955	1975
Population, in millions	107	165	210
Gross National Product—billions	$127	$374	$705
Gross per Capita Income—1953 prices	$1,195	$2,294	$3,500
Index G. N. Product per Capita	100	192	293
Index Farm Output	100	160	205
Agricultural Output per Man-Hour	100	264	422
Industry Output per Man-Hour	100	220	330
Number of People Supported by One Farm Worker	8.3	19.7	44
Production per Crop Acre	100	122	150

dwindling labor force. Each farm worker provided food and fiber for 8.3 people in 1920, 19.7 in 1955, and may be expected to increase this to 44 in 1975. In order to achieve this, the tremendous gains of 2.64 times in productivity of farm labor during the period 1920-1955 must be increased to 4.22 by 1975.

There is every reason to believe that this can and will be achieved, even though it is projected as a 60 per cent increase in efficiency in two decades. If no further progress is made in controlling pests, other means aggregating 75 per cent improvement will have to be achieved since each gain will be depreciated by about 21 per cent. If present losses from pests could be reduced 50 per cent, the demand on other production methods might be reduced to one half of this amount. Obviously, we cannot afford to be satisfied with the progress to date, much less give up any of the pest control devices we have at our disposal.

One of the favorite indoor sports of the somewhat neurotic Americans today is to define our standing in commerce and industry in relation to that of Russia. You might think that, since our national economy grows only about three per cent per year while theirs increases six to eight per cent, we are losing the world struggle. A few statistics may help our perspective. Our nation will be on a par with Russia when we abandon three fifths of our steel production capacity, plug two thirds of our oil wells, eliminate 95 per cent of our motor manufacturing, destroy two out of every three hydroelectric plants, rip up two of every three miles of railroad tracks, sink eight of every nine ocean-going vessels, scrap 19 out of every 20 cars and trucks, destroy 40 million TV sets, discontinue 9 of every 10 telephones, burn 7 of every 10 homes—in substance, if we were to reduce our living standards by 75 per cent, and transfer 60,000,000 of our people from urban existence back to the farm. We could readily do everything but the last and recover very handily. However, if we were to put all those people back on the farm to run an archaic system, America would no longer exist as we now know it.

Pesticides have played a major role in freeing our people from farms for greater service elsewhere. It has been estimated that one man in a chemical factory making the herbicide 2,4-D can do more for agriculture than 250 men with a hoe. Under many circumstances he can do much more because he makes it possible to remove many deep-rooted perennials that would only sprout again as soon as they are cut off by hoe, mower, or cultivator, and to clear up weeds in wet fields that cannot be weeded successfully by cultivator or hand methods. Chemical weeding is simply a common-sense use of manpower.

It costs fully as much to plow, fertilize, fit, and seed an acre of land where pests will run rampant as one that is fully productive. The more fertile and better-cared-for fields require the protection that pesticides provide. This can be illustrated by examining data from experiments made with fungicides in commercial fields.

Protective fungicides are applied to seed to prevent seed decay of peas, corn, peanuts, and many other crops. If this is not done, fields may have to be reseeded at a less favorable planting time whenever cold, wet weather prevails. Even if there is not a stand failure, imperfect occupancy prevents maximum utilization of space and soil fertility.

Typical data from a field of peas seeded with treated and untreated seed are presented in Table 3 to illustrate this principle. The combination of the seed treatment and best fertilizer treatment doubled the yields, but the fertilizer treatment alone could produce only a 30 per cent gain. Relatively little of the investment in fertilizers was recovered as better yield from untreated seed plots because fewer plants occupied the growing area. Approximately 75 per cent of the

TABLE 3. PRODUCTIVITY OF WISCONSIN EARLY SWEET PEAS GROWN FROM SEED TREATED WITH A PROTECTIVE FUNGICIDE IN SOILS WITH DIFFERENT FERTILITY LEVELS

Treatments Applied		No. Plants/ 10 Feet of Row	Yield of Green Peas lbs./acre
To Seed	To Soil*		
Spergon	None	75.2	2,039
Spergon	5–20–5	75.8	2,834
Spergon	Manure	72.4	2,160
Spergon	Manure + 5–20–5	75.2	2,679
None	None	49.0	1,422
None	5–20–5	45.2	1,780
None	Manure	50.3	1,296
None	Manure + 5–20–5	52.2	1,832

*Fertilizer application of 600 lbs./acre of 5–20–5 and 10 tons of manure per acre.

treated seed and 45 per cent of the untreated ones had produced plants that survived the seedling stage. There was no evidence either in the stand or the yields to support the often-repeated claim of poorly informed laymen that manures and organic matter can control disease and produce better yields than balanced fertilizers.

In modern agriculture, seeding rates are controlled to within 10 per cent of the desired level by drilling or use of the planter. The stand requirements for different classes of soil and climates have been determined by careful experimentation, so most farmers sow seeds at the optimum level. They cannot afford to sow more seeds on the assumption that diseases will destroy a certain percentage because weather conditions may not favor seed decay and damping off. In such cases an excessive seeding rate would reduce yields by creating over-competition between the crop plants. The only method of avoiding excessive extremes in the crop population is to treat the seeds and sow them at the rate desired.

The cost per acre of this insurance will range from three cents for a lightly seeded crop of large plants such as corn to 70 cents for a densely seeded crop such as peas. There are voluminous data on the different crops to show that the immediate gain in productivity will vary from 0 to 100 per cent with an average of 20 to 30 per cent in different localities. A few estimates on pea seed production in the United States would indicate that an investment of $775,000 in chemicals and labor in treating seed probably returns $9,913,000 worth of green and dried peas.

The real significance of this treatment, however, lies in the increase in farming efficiency. Because of it, a farmer can invest heavily in fertilizer, employ expensive mechanical equipment to control the rate and depth of seeding, and plant seed at a favorable time of the year to obtain maximum benefits from the soil and climate. Seed treatment therefore becomes a factor in a very precise and highly integrated technology. Without it the farmer would be at a loss to decide how much seed should be sown, how much fertilizer should be used, etc.

The same principles apply to protecting plants after they pass the seedling stage. The debilitation caused by insects or disease agents or competition from weedy plants can unbalance the soil-climate-crop relationship desired for maximum benefits. This can be illustrated by the defoliation of tomatoes caused by the early blight fungus (*Alternaria solani*). In a commercial field where unprotected plants were heavily defoliated by September 1, the yields of marketable tomatoes were increased from 7.6 tons to approximately 16 tons by use of fertilizers on unprotected plants, but where the same plants had been protected by spraying with an insoluble copper fungicide, the yields went up to 20 to 24 tons per acre (Table 4).

When these fruits were harvested, sent to a commercial factory, graded, and sold at $23.00 a ton for U. S. No. 1 and $12.00 per ton for U. S. No. 2, they grossed the following amounts: Unsprayed and unfertilized plots, $128 per acre (approximately the cost of production), fertilized but unsprayed plots, $264 per acre, while fertilized and sprayed plots grossed $464 (Fig. 1). The net gain from fertilizer treatment in unprotected plants was $96 and in sprayed ones $284. Under the conditions of this experiment it was foolish to have fertilized heavily or to have sprayed diligently unless the other treatment was also applied. The combination assures approximately twice as much net earnings per man-hour of labor as either treatment alone.

The gain in farm efficiency from use of pesticides on animals is no less profound than that on crops. The elimination of internal parasites from breeding and fattening animals is prerequisite to a profitable operation. The science of animal nutrition and breeding has made it possible to increase the feed-efficiency ratio to unbelievably low levels in the past 30 years. In the case of swine the old standard of 800 pounds of grain per 100 pounds of pork was outmoded many years ago, and the 400-to-100 ratio prevailing during World War II has been reduced another 25 per cent or more. All this research is meaningless if endoparasites destroy the alimentary tract and interfere with normal metabolic processes. The use of acaricides has taken

TABLE 4. YIELD OF SPRAYED AND UNPROTECTED TOMATOES IN A COMMERCIAL FIELD WHERE EARLY BLIGHT WAS SEVERE

Fertilizer Treatment Applied to Soil	Yield of Tomatoes (tons/acre)	
	Unprotected	Sprayed
None	7.59	10.74
Manure + superphosphate	12.56	15.12
1,200 lbs. 3–12–6	12.53	14.65
1,200 lbs. 3–12–12	16.46	24.29
1,200 lbs. 3–12–6 Sp.	12.43	21.11
1,200 lbs. 6–12–6 Sp.	14.86	20.93

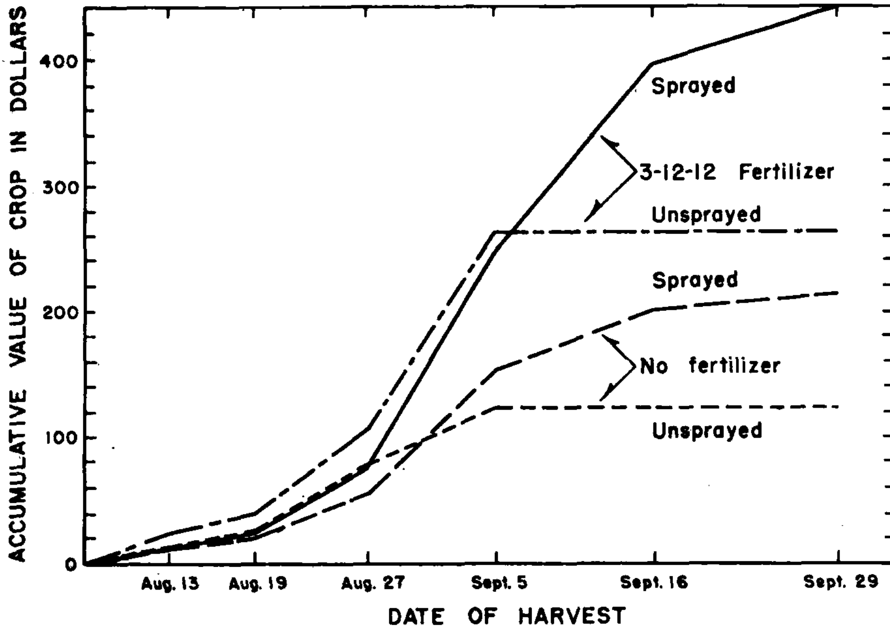

FIGURE 1. Returns from sprayed and unprotected tomatoes in a commercial field where early blight was severe.

much of the hazard out of feeding operations. Even more sensational has been the observation that trace amounts of tetracycline antibiotics may very easily double the metabolic efficiency and growth rate of swine and fowl.

The ectoparasites present no less hazard to the livestock industry. The nervous energy, restlessness, and failure to feed properly when attacked by flies, mosquitoes, and other pests is reflected in growth and feeding efficiency. There is substantial evidence that the gain of steers protected from these pests may be 400 pounds or more, better than unprotected animals on the same diet. The 15 per cent gain in milk production per cow in the six years following introduction of the chlorinated hydrocarbons may very well be attributable to the substantial reduction of flies around stables and pastures.

It takes as much food and labor to care for a healthy relaxed animal as it does one that is restless and busy switching away irritating pests. It is only by removing the pests by systemics or external applications of chemicals that livestock can reach maximum productivity of meat, milk, and fiber.

Maximum Utilization of Natural Resources

The use of pesticides as needed has given the farmer confidence to make full use of his land resources. This has led to revision of many of the older practices and abandonment of others. Without these changes it would not have been possible to supply the demand for intensive cultivation in the locality of processing plants and otherwise concentrate production where it would do the most good.

It is now possible to shorten crop rotations drastically so the favored crop of an area can be grown with greater frequency. The seven-year rotation is prehistoric and five-year ones are relatively rare except in areas where livestock grazing is practiced extensively. The three-year rotation is almost standard in intensively cultivated areas. The means of inhibiting, avoiding, or suppressing the build-up of insects and disease agents are now at hand for many crops.

It is most unfortunate that every chemical need has not been fulfilled. For example, the root rots of peas caused by a complex of five fungi rapidly become established in the soil after five to seven years' cultivation of the crop in an area. A rotation of approximately five years is necessary to suppress the population of pathogens. Unfortunately, the pea canners who must operate on an annual basis and the farmer who needs vine ensilage on his livestock farm find this most uneconomical. There is little the farmer can do but reduce his acreage but the canning company can partially solve its problem by dispersing viner sub-stations over a wide agricultural area. However, this is done at a great loss in operational efficiency. The usual experience is that even around these viner stations pea culture is pushed farther and farther away, so that after 10 or 15 years of operation pea vines may be hauled 30 to 50 miles from the farm and back. Fortunately, other pests on the aboveground parts of this crop, such as the destructive aphids and weevils, can be controlled by proper use of insecticides so that only the root diseases remain to be conquered.

As indicated by the data in Table 1, the wise use of pesticides permits maximum use of the preferred farming resources. As the yields per acre are increased, hundreds of thousands of acres of land can be retired for other crop uses. This naturally concentrates any particular crop in the area where it will do best and release the marginal land for other uses. With the upsurge in use of pesticides in the last decade we have been able to retire much land from cultiva-