PEST CONTROL: A NEW INDUSTRIAL REVOLUTION

A. S. CRAFTS

University of California, Davis, California 95616, U.S.A.

ABSTRACT

Industries such as manufacturing, mining, and transportation have been experiencing mechanization and automation for well over 100 years. Agriculture, in contrast, has lagged behind and only in the last 30 years have these processes been adopted. Long considered a way of life rather than an industry, farming is now becoming as highly industrialized as the traditionally organized businesses.

Pest control, one of the later developments of the agricultural industry, has had a tremendous impact on farming methods, and in turn on crop production. Many of the high yields being reported almost daily in the agricultural press are the result, not alone of pest elimination but also of the 'new agronomy', that is, closer more regular spacing of plants, mechanical thinning, and the higher fertility level which these new methods allow. Yields of all of our staple crops are being obtained which were unheard of 20 or 30 years ago.

Herbicides, with which I am most familiar, have increased from half a dozen products available in the early forties to over 100 well-established chemicals. These are presently available in literally thousands of formulations.

What are some of the new developments in this rapidly progressing field? (i) In addition to the acid-arsenical formulation and sodium chlorate, we now have translocated herbicides to handle practically all known perennial weeds. A few of these are 2,4-D, 2,4,5-T, MCPA, amitrole, dalapon, 2,3,6-TBA, dicamba, the methane arsonates and picloram. (ii) We now have selective foliar sprays to control many annual weeds. These include barban, bromoxynil, ioxynil and propynil, to name only a few. (iii) We have a great number of soil-borne selective and non-selective herbicides to handle special weed problems in crops and in non-agricultural situations. These include the urea and uracil herbicides, the triazine materials, a number of carbamates, substituted amides and phenols. (iv) A number of the newer chemicals are proving effective in killing aquatic weeds in lakes, reservoirs and rivers; some of these are paraquat, endothal, aqualin and fenac.

While this arsenal of weapons for fighting weeds has revolutionized many aspects of crop production including range management and forestry, pesticides have brought many new and perplexing problems. Volatilization drift, misapplication and soil residues are some of the aspects that have plagued the people who apply and use these new chemicals. This is the problem that is worrying biologists, ecologists and public-minded people

around the world. There are no easy answers to these difficulties because they are often bounded on one side by limited yields and ultimate starvation, and on the other by injuries, problems of public health and possible permanent damage to our atmosphere and soils. The public health aspects are under strict surveillance in the United States and in many other countries, and probably more and better food is available than in any previous time in history. However, the atmosphere and soils are more difficult to monitor and it is in these areas that much research is needed if we are to avoid catastrophy in the future.

★ ★ ★

When man first used fire to burn the forests and prairies to open them for access and better hunting he started the manipulation of his environment. When he emerged from the forest and developed the arts of agriculture he started a chain of reactions which has continued to this day. Thus his environment has been permanently and irreversibly altered—in some ways improved but in many ways harmed. Plowing often resulted in soil erosion. Early efforts at irrigation often resulted in a rise of salts which ruined thousands of acres for agricultural production. Denuding of forests produced destructive floods. And urbanization has shrunk the acres available for crops; never has this been more serious than today.

With the invention of the steam engine 200 years ago the stage was set for the industrial revolution. The population in Britain was increasing rapidly, agricultural experimentation led to improved farming methods; cattle breeding was undertaken. The invention of the steam engine and other labour-saving devices brought about great changes in the management of industry, in factory production, and in the relations of capital and labour. By the beginning of the nineteenth century the smoke and grime of industry were mixing with the fog of Britain's manufacturing cities; air pollution had made its appearance as a menace. Soft coal, petroleum, chemical vapours, filter and refinery fumes, automobile exhaust and now pesticides have all added to the burden being borne by our atmosphere.

The industrialization of agriculture proceeded more slowly. The threshing machine in 1786, Whitney's cotton gin in 1793, the McCormick reaper in 1831, the rotary disc cultivator in 1873, the centrifugal cream separator in 1879, the first commercial automobile, the forerunner of the truck and tractor in 1891 and the combined harvester in 1888 are a few of the milestones of this process.

World War I had an accelerating influence on the progress of agriculture. Tractors and trucks were greatly improved to aid in the movement of weapons and materials. The aeroplane, first used in scouting was developed into an instrument of offensive warfare. The Stearman biplane much as it emerged from World War I is still the workhorse of agricultural aeronautics, being used to apply fertilizers and pesticides, to seed crops and in some instances to haul fencing into inaccessible country.

Again during World War II tremendous improvements were made in trucks, tractors and aircraft and all of these have been passed on to agriculture. The diesel motor became the standard power plant for trucks, tractors, buses, and on the land this led to lowered costs for all mechanical processes.

Improved transport has led to rapid truck service from farm to factory to market. Jet aircraft have been adapted to air freight so that it is now possible to deliver fresh flowers, fruit and vegetables from California to the eastern seaboard of the United States in about 4 hours, from Hawaii to San Francisco and Seattle in around 5 hours. Improved tractors and soil-moving equipment not only lower building costs of highways; they make possible large land levelling and drainage projects. Mechanization and automation have helped the dairy business and the preparation of animal feed. Large multiple machines make it possible to work the land and apply seed, fertilizer and pesticides in a single operation.

Self-driven combined harvesters have revolutionized the harvest of small grain including rice. Corn pickers, potato diggers, tomato, cabbage, lettuce and onion harvesters are presently in use on these crops as are shakers and pickers for tree fruits, melons, pineapples and grapes. And researches by agricultural engineers, plant breeders, horticulturists and agronomists are hastening the day when hand labour in agriculture will have vanished from the scene.

Pest control has been the latest of the grand developments in the industrialization of agriculture. At the end of World War II, DDT and BHC had appeared. Typhus had been checked in Italy during the war and in the U.S.A. cases reported were reduced from 5000 to 500 between 1945 and 1951. Malaria and yellow fever were virtually eliminated in many tropical countries. *Figure 1* shows the clinical malaria cases as percentage of total

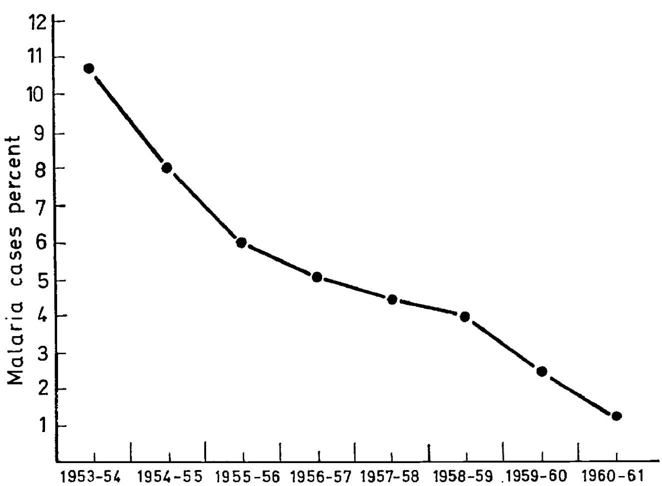

Figure 1. Dispensary statistics—clinical malaria cases to total cases (in India)

cases in India from 1953 until 1961. During this period the number of people protected against malaria has risen from 30 to 200 million. Dr E. F. Knipling of the Agricultural Research Service of USDA estimates that 5 million lives have been saved and 100 million illnesses have been prevented through the use of DDT[10]. Meanwhile the impact on food production, though less dramatic, was very real. Pounds of milk per cow was almost doubled during the decade 1945–55. Potato production went from 150 to 250 bushels per acre; tomatoes from 5 to 10 tons per acre.

Following these initial dramatic results of the introduction of effective new insecticides the chemical industry attacked the problem of pests in earnest. New insecticides of extreme potency were soon made available, fungicides and herbicides of great potential were introduced. And production of all food and fibre crops was upgraded, the extent depending upon the seriousness of the pests and the potentialities of the crop varieties.

At this point it should be emphasized that pesticides as such do not increase crop yields; this is determined by plant breeding, selection, and the provision of optimum nutrient conditions. Given high yielding varieties and adequate fertilizer, pesticides enable these varieties to produce their maximum yields.

Having available the new soil-borne selective herbicides that can be used by the pre-emergence method it is now possible to practice what some have termed the "new agronomy". This procedure, which is being used in many countries, involves closer, more regular spacing, high levels of fertilizer, precision seeding and mechanical thinning. Using such methods and employing the new shorter, erect foliage varieties, high yields of wheat, barley, corn, sorghum and rice are being reported from most of the nations that practice advanced agricultural methods, and from a few of the emerging countries who have sought advice from the former. *Table 1* gives data on production and yields of 8 major crops from 1938 to 1968 in the U.S.A.

Table 1. Production during the past thirty years of some major crops. All values in 1,000 units

Crop	1938	1948	1958	1968
Wheat, bu.	919,913	1,294,911	1,457,435	1,570,433
Barley, bu.	256,620	315,537	477,368	418,168
Corn, bu.	2,548,753	3,605,078	3,724,969	4,374,840
Sorghum, bu.	67,210	131,384	581,012	738,507
Rice, cwt.	23,628	38,275	44,760	105,322
Soybeans, bu.	61,906	227,217	580,250	1,079,662
Cotton, bales	11,943	14,877	11,512	10,822
Potatoes, cwt.	213,509	269,937	266,897	293,438
Per acre yields of some major crops 1938–1968				
Wheat, bu./A	13·3	17·9	27·5	28·4
Barley, bu./A	24·2	26·5	32·3	43·7
Corn, bu./A	27·7	42·5	51·6	78·5
Sorghum, bu./A	14·3	18·0	35·2	52·9
Rice, cw./A	21·9	21·2	31·6	44·7
Soybeans, bu./A	20·4	21·3	24·2	26·6
Cotton, lbs./A	235·8	311·3	466·0	511·0
Potatoes, cw./A	74·4	136·3	186·9	213·0

Compiled from Agricultural statistics USDA.

The principles of the new agronomy are being applied not only to the cereal crops noted above but to leguminous crops, vegetable crops, tree and bush fruits and fibre crops. And the plant breeding procedures required to produce the high yielding varieties go hand-in-hand with work on disease and insect resistance so that, given continuing results comparable with those obtained within the past two decades, we may look ahead with optimism for continual increases in yield and productivity. *Figure 2* shows the effects of the introduction of modern pesticides on the incidence of malaria and typhus in the United States, and on increased yields of milk, potatoes and tomatoes.

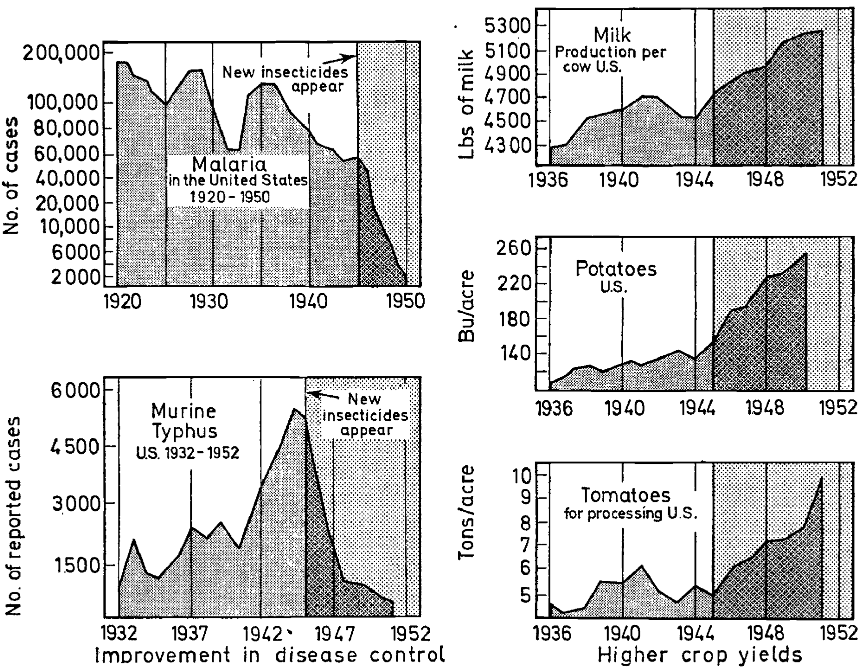

Figure 2. The differences brought about by modern insecticides[12]

Let us now turn to herbicides with which I am most familiar. When I entered this field in the mid-twenties there were available arsenic, sodium chlorate and carbon bisulphide all of which were being tested and applied in the fight against weeds. We at Davis first suggested using boron compounds in the early thirties and the dinitro material Sinox was introduced from France in 1937. Ammonium sulphamate followed in 1942. In our book *Weed Control*[16] methods for testing the herbicidal properties of these compounds were described and herbicide selectivity was analysed in terms of plant morphology and formulation properties.

The great revolution in weed control came in 1945 with the introduction of 2,4-D. Within two years herbicide usage jumped from thousands to millions of acres; selective control of broadleaved annual weeds became standard practice in the major grain-growing areas of the world. And weed control research underwent a tremendous development.

The earliest reports on weed control with 2,4-D described trials in which bindweed or wild morning glory (*Convolvulus arvensis*) was destroyed following foliar application. When the flurry of excitement over the use of

2,4-D against annual weeds cooled down, experiments on the use of the chlorophenoxy herbicides against perennial species were carried out and it soon became evident that many of these more pernicious weeds would succumb to these compounds. And 2,4,5-T emerged as the most effective material for controlling brush and weedy trees. This gave added impetus to the rapidly progressing field and added tremendous acres of range, forest and right-of-way to the acreage being treated.

This is not the place to go into a detailed account of the new developments in weed control during the past two decades. I do want to mention the introduction of substituted urea and symmetrical triazine compounds for treating weeds by application pre- or early post-emergence to the soil. The addition of the uracil compounds, the introduction of picloram as a highly potent translocated herbicide, the appearance of propanil and diallate for water grass control in rice and recent introduction of highly selective compounds for eliminating weeds in sugar beets, cotton, tomatoes, alfalfa and cereals by pre-emergence treatment are a few of the highlights. *Table 2* presents data on the extent of weed control in the United States during the period 1959 to 1965.

In relating this story of the rapid development of chemical weed control I do not want to imply that this field alone was making such progress. Developments of comparable magnitude were taking place in use of insecticides and fungicides, all of which have contributed to the dramatic increases in productivity being reported from around the world. Nor do I wish to give

Table 2. Estimated extent and cost of chemical weed control

Crop or area	*States reporting*			*Acres treated*					
				Total number[a]			*Percent of total acres*[b]		
	1959	1962	1965	1959	1962	1965	1959	1962	1965
	Number	*Number*	*Number*	1,000 *acres*	1,000 *acres*	1,000 *acres*	*Percent*	*Percent*	*Percent*
Corn	40	46	48	20,051	25,302	45,012	25	39	68
Cotton	13	15	17	1,554	5,433	12,479	10	35	92
Soybeans	15	28	29	556	2,827	7,832	2	10	23
Small grains	38	45	44	20,723	18,931	28,735	22	24	36
Rice	4	6	5	502	940	1,390	32	53	78
Peanuts	5	8	9	35	310	797	2	22	55
Sugarbeets	11	15	15	125	362	495	14	33	40
Sorghum	14	25	24	2,093	2,665	5,391	14	23	32
Forage seeds	14	20	15	282	439	221	8	16	9
Sweet corn	—	1	21	—	30	308	—	5	56
Other vegetables[c]	20	36	36	276	1,164	779	10	18	13
Fruits and nuts	12	21	21	10	267	540	5	10	19
Ornamentals	6	15	15	2	51	84	1	25	40
Lawns	17	23	29	60	672	1,134	1	5	14
Hay	20	33	35	272	412	1,269	(d)	(d)	2
Pastures[e]	34	45	40	2,400	4,714	6,671	(d)	2	2
Rangeland[f]	13	20	17	2,011	2,262	3,156	(d)	(d)	(d)
Forest plantings	—	18	17	—	274	117	—	—	—
Noncropland	27	31	27	1,971	3,612	3,306	—	—	—
Aquatics	—	—	13	—	—	84	—	—	—
Total or average	41	50	50	52,923	70,667	119,800	—	—	—

[a] Includes acres treated pre-emergence plus acres treated post-emergence; those acres treated both pre- and post-emergence are counted twice.
[b] Harvested acreage where crops were harvested.
[c] Root crops, cucurbits, vegetable legumes, and solanaceous crops in 1965 and all vegetables except sweet corn in 1959
[d] Less than 1.
[e] Annual, improved perennial, and unimproved perennial.
[f] Mountain, prairie, arid, and rainbelt.

the impression that the use of the new pesticides was an unmitigated blessing for many difficulties were encountered and tremendous amounts of money, time and effort are being expended every day in regulating pesticide usage so that our environment will remain habitable. I would now like to spend some time in a consideration of some of the problems inherent on the use of chemicals in the production of food, feed and fibre.

From its inception the use of sodium arsenite proved hazardous to man and animals. Thousands of head of livestock were killed where this poison was used to control weeds along railway rights-of-way and many human deaths are on record from accidental ingestion of the chemical. I need not detail the fire hazards inherent in the use of sodium chlorate; here again human lives were lost and tremendous losses by fire were experienced. Even the relatively safe dinitro compounds caused loss of life in Britain and many man hours of time were lost from illness wherever these materials were applied in the forms of sprays. Carbon disulphide forms an inflammable vapour and its use against perennial weeds involved hazards. Boron compounds proved to be the safest to use; mixtures of boron and sodium chlorate were safe, as borax counteracted the hazards of sodium chlorate. DDT and 2,4-D proved harmless as direct poisons to man and animals and huge quantities of these chlorinated materials were used before their residual effects were recognized. The earliest signs of danger came from the drift and volatilization of 2,4-D compounds as they affected neighbouring crops. Very soon after its introduction as a selective spray, 2,4-D-growth-regulatory symptoms were noted

in the United States,1959, 1962 and 1965

Cost of herbicides including cost of application and materials for all treatments						*Acreage treated by—*					
Total			*Average per acre*			*Farmers*			*Custom*		
1959	1962	1965	1959	1962	1965	1959	1962	1965	1959	1962	1965
$1,000	$1,000	$1,000	*Dollars*	*Dollars*	*Dollars*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
37,980	57,600	144,267	1·89	2·28	3·21	82	83	80	18	17	20
4,709	16,805	59,678	3·03	3·09	4·78	92	91	90	8	9	10
2,315	10,835	35,249	4·16	3·83	4·50	98	90	93	2	10	7
37,095	29,579	53,375	1·79	1·56	1·86	75	65	58	25	35	42
889	6,250	12,638	1·77	6·65	9·09	13	10	8	87	90	92
116	2,565	6,337	3·31	8·27	7·95	100	97	88	—	3	12
625	2,237	4,179	5·00	6·18	8·44	94	90	92	6	10	8
6,512	5,258	22,121	3·11	1·97	4·10	40	66	74	60	34	26
1,868	2,416	1,527	6·62	5·50	6·91	80	62	78	20	38	22
—	187	1,750	—	6·23	5·68	—	95	81	—	5	19
1,418	10,415	7,969	5·14	8·95	10·23	84	79	72	16	21	28
98	2,397	7,029	9·80	8·98	13·02	99	86	86	1	14	14
45	969	1,743	22·50	19·00	20·75	70	34	42	30	66	58
1,489	15,368	26,750	24·82	22·87	23·59	82	83	58	18	17	42
1,692	1,794	5,224	6·22	4·35	4·12	81	78	79	19	22	21
5,789	13,340	16,551	2·41	2·83	2·48	74	64	84	26	36	16
6,174	6,265	15,748	3·07	2·77	4·99	37	37	13	63	63	87
—	2,752	1,492	—	10·04	12·75	—	34	57	—	66	43
19,738	83,714	68,470	10·01	23·18	20·71	30	26	39	70	74	61
—	—	1,922	—	—	22·88	—	—	44	—	—	56
128,552	270,746	494,019	2·43	3·83	4·12	—	—	—	—	—	—

and 1962.

on grapes, cotton, tomatoes, alfalfa, melons and other susceptible crops. Almost immediately lawsuits appeared in the courts, there were public hearings in the Departments of Agriculture in many states and in 1950 hazardous areas were set up by law in California where spraying with 2,4-D was prohibited between March 15 and October 15. Many hearings since this date have altered the shape and size of the hazardous areas but there have been few modifications of the original intent of the law, namely to prevent injury of susceptible crops by prohibiting the use of 2,4-D. Even in areas where this herbicide may be used, all commercial applications on a field scale come under the jurisdiction of the county Agricultural Commissioners. Similar laws exist in many other states.

Since the problems with 2,4-D, a number of other types of herbicides have brought on difficulties. The substituted urea and symmetrical triazine materials, when used on roadsides or drain ditches, have caused injury, and in some cases death of roadside ornamentals and orchard trees. Our latest problem situation in California involves the use of propanil to control barnyardgrass in rice. After this chemical had come into general use in the northern Sacramento Valley rice growing areas, many prune trees in the district began to decline. Within the past year some trees have died, and there is now in the courts a lawsuit, brought on by the prune growers against chemical companies supplying propanil and against rice growers using it; this suit involves several millions of dollars.

Meanwhile it has been found that certain chlorinated hydrocarbon insecticides including DDT, dieldrin and chlordane are stored in body fat and bone marrow of man and animals. These and other pesticides enter food chains, and build up to high levels in some members of the chain resulting in injury or death.

This matter was brought to a head in 1962 with the publication of Rachel Carson's *The Silent Spring*[6]. Since that time there have appeared tons of publications on the pros and cons of pesticide usage. Let us look into some of the controversial aspects of this problem and some of the public policy actions that are in practice to safeguard public health.

Pesticides first became a subject for legislative action by the Federal Government of the U.S.A. when Congress passed the Federal Insecticide Act. Regulation has been strenghtened from time to time to protect both the user and the consuming public.

1. The Federal Insecticide, Fungicide and Rodenticide Act of 1947 requires that manufacturers prove to the U.S. Department of Agriculture that these pesticides are effective, and that they are safe for the user and the public when applied according to instructions and warnings on the label. Labelling must indicate what pests the chemical will control, the crops or livestock it can be used on, the quantities to be applied, and any necessary safety precautions.

2. The Miller Pesticide Residue Amendment to the Federal Food, Drug and Cosmetics Act of 1938 was passed in 1954. It demands that the manufacturer provide detailed scientific reports on how much residue, if any, will remain on a crop, and how much could be tolerated in a crop. This information is used by the Food and Drug Administration to set tolerances for the

trace amounts of pesticides that may be allowed on market produce and which would not prove hazardous to the consumer.

Unless a tolerance has been established, any residue is illegal, and the food is subject to confiscation. Unless a tolerance has been set for a given chemical, the USDA under provisions of the insecticide act, will refuse permission for sale of the product. And many states have similar laws governing chemicals not involved in interstate commerce.

Congress has assigned the USDA the responsibility for registration of safe, effective agricultural chemicals. No pesticide can be sold in interstate commerce unless it and its label has been registered by the USDA. State laws require registration of pesticides produced and sold within a state. The label is required to carry safety warnings and necessary instructions for safe handling, for antidotes and for first aid in case of accident.

If there is any possibility that a residue remains on food following application of a pesticide, a tolerance from the Food and Drug Administration is required. This tolerance is set below the amount of a pesticide which scientists have determined can safely remain as a residue without injury to the consumer, and is no more than necessary for control of the target pest. Often hundreds of pages of documents, proving that residues left on each crop are perfectly safe, are submitted before a tolerance is established. Toxicological tests proving safety and chemical tests measuring the quantities of residue that are left on crops when directions for use are followed, are included in applications for registration. Pharmacologists and chemists of the Food and Drug Administration study each petition for registration carefully. If satisfied with the evidence with respect to residues and safety, a tolerance is set at a level that provides a wide margin of safety. As a rule a safe dosage for humans is set at about one one hundredth of that considered safe for rats. In some foods, such as milk, no residue of any chemical at any level is permitted. Agricultural chemicals are kept under constant surveillance by the Food and Drug Administration. It spot-checks food on a regular schedule, analysing for pesticides in excess of tolerance. If above-tolerance amounts are found, the food is seized and may be destroyed. The famous cranberry case in 1959 is an example.

Manufacturers of pesticidal chemicals have tested to determine safe practices for many years. Today, laws require these tests, and as such they represent recognition by State and Federal Governments of the economic necessity of pesticides and their hazards. These laws also set standards by which manufacturers are required to prove that a new chemical is effective and that warnings on the label will protect the user. They recognize that residues will appear on crops, and they established procedures by which the amount of residue may be limited to a level that will safeguard the consumer.

The type of questions asked by Federal and State agencies in registration procedures are as follows:

1. What happens if the chemical gets on the skin or is inhaled?
2. What amounts are left on crops for how long?
3. Does it show up in milk or meat of animals fed treated crops?
4. What laboratory procedures prove these findings?
5. What amounts may occur in foods?

The Union Carbide Chemicals Company tells that it took five years of testing to answer these and many other questions concerning Sevin, a carbamate insecticide. Researchers used 1900 experimental animals, made 220 biochemical determinations and filled 4100 pages of laboratory records during this 5-year period. The tests involved safety, efficiency, residue, and fish and wildlife studies. For example, goldfish were found to tolerate 200 times as much Sevin as DDT and this insecticide proved safe for salmon and bluegills. Reports on the costs involved in the introduction of a new pesticide usually run into millions of dollars and only large chemical industries can afford the necessary research, testing and development. In spite of this fact, very many companies are actively engaged in synthesis, testing and development of new pesticides in spite of the fact that they are being deterred by the regulations and high attendant costs.

There can be no doubt concerning the need for the present high levels of agricultural production made possible by the use of modern pesticides. *Table 3* shows world statistics on Population, Income and Food Consumption

Table 3. World statistics on population, income and food consumption[a]

	Population 1,000	*People* 100 *acres*	*Income per capita*	*Food consump. per capita*	*Calorie consump. per capita*
United States	179,900	16	$2,342	$109·2	3,190*
Canada	17,900	12	1,482	104·0	3,100*
Oceania	12,700	1	1,256	117·2	3,260*
North Europe	211,283	88	1,093	93·2	3,060*
South Europe	96,967	70	445	67·1	2,720*
Japan	93,200	527	395	51·2	2,360 Std[c]
River Plate	22,753	6	365	97·2	3,200*
South Africa	17,619	4	360	57·4	2,670*
Mexico	34,934	15	281	43·7	2,580*
South America	51,549	25	263	49·4	2,260
Central America[b]	32,328	61	227	47·5	2,240
Brazil	70,551	23	211	55·5	2,710*
West Asia	79,391	16	193	42·4	2,350
North Africa	84,813	19	112	35·4	2,210
East Africa	48,563	10	86	40·9	2,390*
Other E. Asia	246,238	154	82	35·8	2,150
W. Central Africa	108,808	17	81	31·3	2,460*
Communist Asia	712,907	100	69	23·5	1,790
India	431,700	100	69	29·8	2,060

[a] From the world food budget: 1970, Foreign Agric. Econ. Rept. No. 19.
[b] Includes the Caribbean area.
[c] Japan is considered to have the minimum daily requirement. Those marked with asterisk (*) are above this level.

taken from a report[17] of the Foreign Agricultural Service. Of the 19 areas reported 7 are below the minimum daily calorie consumption level; these 7 areas have a total population of 1,638,926,000 people. Thus about two-thirds of the world's population live in countries with nutritionally inadequate national average diets.

A 100-man panel, set up in 1966 by President Johnson of the U.S.A., reached the conclusion that "A solution to the world food problem during the next 20 years is biologically, technologically and economically possible. Politically, however, one cannot but be pessimistic about mankind doing the necessary things to keep famine, pestilence and war from sweeping the world. This does not, however, relieve the United States, and the rest of the world from adopting major programmes to meet the challenge... the programs may require between 4 and 5 billion dollars a year and must be put on a long range basis." This is a mere fraction of the cost of the Vietnam war.

To show how farmers are winning the battle against insects I would like to cite a number of case histories reported by Union Carbide[12]. *Table 4* presents the data. Obviously we in the U.S.A. are producing more and

Table 4. Case histories on commodity costs in the U.S.A.

Case number	*Commodity*	*Today*	*Price without insect control*	*Annual loss in percentage and in dollars* Forage	Milk
1	milk	27¢/qt	34¢/qt	4%, $30 million	8%, $400 million
				Product, per cent	Product, dollars
2	sweet corn	20¢/can	52¢/can	11·6	$7·8 million
3	beans, canned	29¢/can	87¢/can	9·0	$3·6 million
4	apples	68¢/bag	$2·00/bag	11·0	$30·0 million
5	vegetables return	$300/garden	$100/garden	66·0	$150·0 million
6	cotton	25¢/lb	40¢/lb	15·0	$335·0 million

better food today than at any time in the history of the world. Whereas it took 120 hours of labour to buy food for a family of five for one month in 1920, 91 hours in 1930, 57 hours in 1940, it now takes less than 39 hours. Thus efficiency in terms of man hours required to produce our food has increased over three-fold in about 30 years. This would not be possible without pesticides.

I have noted the sorts of production increases brought about by the use of pesticides, and the measures taken to insure a safe and wholesome food supply. What are the long term effects of the use of such materials. Conservationists, ecologists and plain citizens are asking about such effects and demanding that research be conducted to find answers. Thought along these lines was stimulated by *The Silent Spring*[6] but the use of millions of pounds of chemicals as defoliants in Vietnam has brought the problem to crisis proportions. As a result of a letter sent by 12 prominent scientists to President Johnson protesting the use of deoliants in Vietnam the Department of Defense commissioned Midwest Research Institute of Kansas City, Missouri to write a report on long term ecological effects of extensive or repeated use of vegetation control chemicals. Because less than 6 months time was allowed for presentation of the report, it was made under severe pressure.

In late October 1967 a committee of five experienced weed-control research men was appointed by Dr A. G. Norman, Chairman of the Division of Biology and Agriculture of the National Academy of Sciences. This committee met for one day on November 8, 1967, and heard members of Midwest Research Institute present various portions of the report. I was a member of that committee. We took back home with us portions of the report which we read, edited and corrected and returned to Midwest.

On December 5, 1967, I received a final corrected copy of the Midwest report. I read this and at the request of NAS wrote a letter listing my individual reactions to the report; this was mailed to Washington on December 19. The other committee members sent similar letters, and these were later summarized by Dr Norman and a summary report was submitted to Dr Fredrick Seitz, president of NAS. He in turn relayed this summary to Dr John S. Foster, Director of Defense Research and Engineering of the Department of Defense.

The Department of Defense released a final report, based upon the original report and upon their interpretation of the letters from Dr Norman's committee on January 30, 1968. Copies of this report were circularized by the National Agricultural Chemicals Association and the report has appeared in many places, e.g.[5, 8].

One obvious fact coming out of the reviews of the Midwest report was that we have very little information concerning *Long term ecological effects of extensive or repeated use of vegetation control chemicals*. After all, we have had most of these chemicals for only 20 years or less. Midwest changed the title of their final draft of the report to *Assessment of ecological effects of extensive or repeated use of herbicides*. They explained that this review covered mainly the use of herbicides under agricultural conditions, not under conditions of tropical jungle.

The summary digest of the Midwest report put out by DOD concluded with 6 pertinent statements:

1. Destruction of vegetation is the greatest direct ecological consequence of using herbicides.

2. Long term effects on wildlife may be beneficial or detrimental.

3. Herbicides now in use in Vietnam will not persist at a phytotoxic level in the soil for long periods.

4. The possibility of lethal toxicity to humans, domestic animals or wildlife by use of herbicides is highly unlikely.

5. Unlike many insecticides, herbicides seldom persist in animal or insect tissues.

6. Indirect effects of herbicides resulting from destruction of aquatic vegetation may produce changes in the biota of the aquatic environment.

In July 1968 the Board of Directors of the AAAS issued a statement in *Science* in which they stated "We note with satisfaction Dr Foster's statement that our government will not sanction use of these agents (herbicides) in Vietnam were it not confident that they have no serious long-term adverse consequences for the environment." They felt "that many questions concerning the long-range ecological influences of chemical herbicides remain unanswered." . . . "We do agree that the use of arsenicals on crops may have serious hazards and we are concerned with the ultimate route taken by arsenical compounds in plants, soil and animals."

Some members of the Board issued a separate statement questioning the use of 2,4-D and 2,4,5-T. From the Midwest report they noted that 2,4-D inhibits nodulation of leguminous plants, an important process in the nitrogen cycle in tropical environments. They also noted that 2,4-D may induce chromosomal abnormalities by interfering with the mitotic apparatus. Two other members issued the statement that "We consider that the use of 2,4-D and 2,4,5-T for defoliation of forest cover probably represents a military devise for saving lives that has an unprecedented degree of harmlessness to the environment."

Thus the controversy has gone on. Unfortunately many who oppose the war in Vietnam on general principles have joined forces with conservationists and ecologists in this protest. Personally I regret the war but we are in it. Over 100 billion dollars and 30,000 American lives have been spent. Having devoted over 40 years to weed control research I am confident that the jungles of Vietnam will survive; without defoliants our death toll might well have been 100,000 to accomplish the same ends.

An aspect of this problem that has not been sufficiently published is the question of what would happen if we listened to the opposition and stopped using pesticides. What *Silent Spring*[6] has already done is well expressed by Dr Louis A. McLean[7]. He says "I submit that the campaign of false fear against the use of modern pesticides has, is, and will cause deaths and sufferings greater than those of World War II. It has been over 12 years since a major new insecticide has been brought to market and this is due to unnecessary controversy. During this interim, daily deaths due to starvation and malnutrition have risen from 6000–7000 per day to over 12,000 per day, not to mention the millions who have died from vector-borne diseases. These lives could have been saved had the efforts devoted to controversy been used to encourage the discovery and wider use of insect controls. Each person who has played a part in the campaign of fear must accept responsibility for his share of the unnecessary toll of human life, a toll that will continue and will increase because we are still handicapped by an environment polluted by that false campaign."

If all use of pesticides were stopped today, within months our food supply would dwindle to about half its present level; the world would be faced with mass starvation. And one cannot but wonder why all of the present concern with the environment should focus on pesticides. For example, a news report on January 12, 1969 stated that the Wisconsin State Natural Resources Department was holding hearings on a petition to ban use of DDT. There are efforts in many places to prohibit the use of DDT, dieldrin, chlordane and other chlorinated hydrocarbon insecticides. Are the people behind these movements fully aware of the consequences of such action? I doubt it.

It is a well substantiated fact that most of our harmful air pollution comes from the exhaust of automobiles, diesel powered trucks and tractors and aeroplane engines. Yet one does not find a concerted campaign against these modern conveniences. Who is to blame for this?

It seems to me that the great amount of publicity and protest over the use of DDT has been misdirected. There are no known fatalities to man resulting in the use of DDT as an insecticide. What the Carsonites fail to appreciate is that the greatest impact of DDT on man has been in the saving of lives. I have cited Dr Knipling's estimate of 5 million lives saved. I'm certain that that is a minimum figure.

Not only have millions of lives been saved; countless additional lives have been prolonged through elimination of malaria, yellow fever, typhus, and other diseases. And the most serious consequence of this has been the accelerated increase in population. Millions of people are hungry today in India, Pakistan, South America, and Asia, thousands are dying from starvation. Whenever an agency adds 10 to 20 years to the lives of 100 million people without assuring that there will be ample food to keep them alive they have sinned. People are dying from starvation by the thousands in the streets of Bombay, Calcutta, Karachi, and hundreds of other cities. Perhaps they had better have died of malaria or yellow fever 20 years ago; starvation is a slow and painful death. And so our real problem is not the hazards of DDT to human life but the moral issue of how people are to die. Perhaps the new wheat, the miracle rice, the opaque corn will alleviate, for a time, our problem of food supply and proper nutrition. But eventually we face the same basic fact; our real problem is population; this is the issue upon which we must exert our major efforts.

References

1 Anon. *Agricultural Statistics*. U.S. Dept. of Agriculture, Washington, D.C. U.S.A. (1967).

2 D. G. Aldrich. *Agricultural Chemicals—Wellspring of Human Progress*. *NAC News Pest. Rev.* **21**(6), 3–6 (1963).

3 Anon. *How to Answer Rachel Carson*. *County Agent and Vo-Ag Teacher*. **18**(11), 28–29 (1962).

4 Anon. *Extent and Cost of Weed Control with Herbicides and an Evaluation of Importants Weeds*. USDA Agricultural Res. Serv. Publ. ARS 34-102 (1968).

5 Anon. *Use of herbicides*. Summary digest of Midwest Res. Inst. rept. *Assessment of Ecological Effects of Extensive or Repeated Use of Herbicides*. *NAC News Pest. Rev.* **24**(4), 6–7 (1968).

6 R. Carson. *The Silent Spring*. Houghton, Mifflin Company, Boston Mass., U.S.A. (1962).

7 L. A. McLean. *Pesticides and the Environment*. *Bioscience* **17**(9), 613–617 (1967).

8 Midwest Research Institute. *Assessment of Ecological Effects of Extensive of Repeated use of Herbicides*. Advanced Res. Projects Agency. Dept. of Defense. The Pentagon, Washington, D.C. U.S.A. (1967).

9 E. M. Mrak. *Agriculture, Food Production, Safety, Wildlife, and Agricultural chemicals in California*. Rept. before Subcommittee on Reorganization and Intern. Organizations of Senate Committee on Govt. Operations UCD, Davis, Calif., Mimeo (1963).

10 R. Pal. *Contributions of Insecticides to Public health in India*. *NAC News Pest. Rev.* **21**(1), 3–5 (1962).

11 President Kennedy's Science Advisory Committee. *Rept. on Use of Pesticides*. The White House, Washington, D.C., U.S.A. (May 15, 1963).

12 J. Strohm. *Our Fight for More and Better Food*. Union Carbide Chemicals Co. New York 17, N.Y., U.S.A. (1962).

13 W. C. Shaw. *Weed Science—Revolution in Agricultural Technology*. Presidential Address, WSA annual meeting, Chicago, Ill., Mimeo (1964).

14 W. C. Shaw. *Research on Pests and their Control*. *NAC News Pest. Rev.* **26**(4), 5 (1968).

15 L. Whitten Jamie. *That We May Live*. D. Van Nostrand & Co. Inc. Princeton, New Jersey, U.S.A. (1966).

16 A. S. Crafts and W. W. Robbins. *Weed Control*. McGraw-Hill, 3rd Edn. (1962).

17 Anon. *The World Food Budget*. Foreign Agr. Econ. Rept. No. 19 (1970).