PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Crop Protection [and Discussion]

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Crop protection

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Crop protection materials and techniques can increase productivity by preventing losses of yield or quality due to invading pests and by increasing the efficiency of men and machines. Spectacular advances have been made during the last 40 years in the availability of new highly active and relatively efficient chemicals which are reliable, safe, easy to use and cheap. Consequently, needs and opportunities for further new chemicals have slowed up in the last few years, while the costs of discovering and developing them have soared. Despite this agriculturally favourable situation, losses of productivity due to pests are higher than they need be. This is particularly so in after-harvest losses due to pest attacks which are still much too high in many crops and many countries.

Increased productivity by better crop protection in the 1980s will demand better post-harvest protection of crops, more use of chemicals on an area basis, and spray programmes against a wider range of pest species. Early preventive usage should also increase, with less reliance on partial late cures. Most of the changing needs of individual farms in the 1980s can be met by the use of existing or forthcoming chemicals alone or in mixtures, or by special formulations or methods of use. As long as the chemical industry is not unduly hampered by irrational fears concerning the human environment, or long-term survival of agricultural soils, or the human race, it will continue to produce still more chemicals to combat existing and new agricultural problems, and should be encouraged to do so. One must, however, doubt whether non-chemical methods as we now know them will make more than a minor added contribution.

In agriculture, any factor is counter productive which reduces germination rate, plant stand, growth, maturity, yield of crop, speed and efficiency of harvesting, storage survival of the crop before conversion or consumption, crop quality, or affects subsequent crops in the same way.

Such effects can be caused by the presence of annual and perennial weeds and grasses, or attack by insects, nematodes, molluscs, rodents, or birds, or infestation by fungi, bacteria or viruses. These competing organisms are for all planning purposes as permanent as man. When their numbers and effects make them a menace to agriculturalists, their swift, effective and sustained control becomes imperative. The consequence of not doing so, or not being able to do so, is apt to be financial adversity or eventually hunger, with all their consequences.

Physical control

Our present-day control possibilities are of three main types: physical, biological and chemical. First, we can aim to control the crop's environment so that it offers a minimum level of attractiveness to resident or incoming pests. This involves mainly physical acts, involving seed, soil, water or waste vegetation, all coming under the heading of good husbandry and hygiene on the farm. On this, I shall say no more, except that such measures are helpful, but rarely enough.

We can also try to modify the environment provided by the crop plant itself, in the form of some genetically ensured property reducing the plant's value as food supply or harbour for invading organisms – that is, we ask the plant breeder to provide built-in protection. The attractiveness and also the difficulties of this need no emphasis. Sufficient to say that fungi and bacteria are problems enough, but the full range of insects, nematodes, broad-leaved and grass weeds seem almost impossible to cater for by such methods, without losing the valuable properties of the crop plants concerned.

Biological control

As the second approach, there are a number of control methods under assiduous investigation, and a few in some practical use, which rely on biological subtleties, usually on the principle of setting a thief to catch a thief. 'Biological control' involves the introduction and encouragement of normally harmless species to dominate and largely exterminate harmful species. 'Integrated control' means the careful adjustment of chemical treatments so that there always remains a population of predatory insect species sufficient to keep the damaging insects down to acceptable levels. A third method is to release into the affected zone large numbers of male insects which have been pretreated chemically or by ionizing radiation so their progeny are non-viable, and the reproductive chain is thus broken.

Other approaches are also based on biological factors. The most potent attractants of insects are specific volatile substances emanating from their opposite sex, or chemical imitators of that stimulus. By using such specific 'pheromones' as a lure, pest insects may be attracted off the crop area, and controlled at the point of attraction. Another interesting possibility has been to arrest the development of insect pests by their exposure to chemicals structurally and functionally similar to the hormones which normally control their development. Other similar thinking has led to the study of the chemical factors which induce hatching of nematode cysts in soil, or could induce germination of weed seeds to permit their destruction before sowing the crop.

Regrettably, but perhaps understandably, little progress has been made towards practical agricultural success by these biologically inspired methods. The most advanced of them have a value as yet limited to partial control of specific pest problems. Each pest problem needs its own particular investigation and solution. They fail when presented with mixed problems, and even when successful are usually slower and less complete than desirable. The major research efforts involved on the reliability and safety of each of them implies that the choice of problem to be worked on is of critical importance. It also implies that crop protection for the next decade or two is most unlikely to rely much on biological methods, and never to the exclusion of others. However, there is a place for such methods – permanent, and high value crops, geographically confined areas such as valleys, islands or glasshouses; and we need more tools, from all sources.

Chemical control

The third measure available to us is by the use of chemicals selected for their ability to control unwanted organisms with safety to the crop, either by their chemical nature, or placement, or timing, or dosage, or formulation or all these.

Scale of effort

A thumbnail sketch of the pesticide industry may here be helpful. Pesticides come almost exclusively from the research and development effort of about 30 companies, mainly in the fine or special chemicals sector of the chemical industry. In the period 1940–72, the number of commercially available pesticides increased from about 60 to 600. Of these about 80 have eventually failed, while 160 have attained a vitally important status in agricultural crop protection. It is probable that between one and two million new chemicals have been synthesized and biologically tested to achieve the present position. The success rate has fallen significantly during the past decade from 1:3000 or so, to 1:7500, as the standards for a potential commercial

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

success have been forced upwards by market or official requirements. The purely biochemical approach to new pesticide synthesis does not seem to have been successful in anyone's hands, so the inventive method remains as intelligent speculative or imitative chemistry.

About 100000 new chemicals are made and tested for such activity each year, and the level of industrial research and development on the discovery of new pesticides is about £80 to £100M per annum. On average, an important new pesticide with multi-national use-potential will absorb at least £1 million on research and development costs, spread over a 4- to 5-year-period, before first sales. The interval from discovery to break-even position, when profit from sales has caught up with cumulative expenditure, is at least 7 years, usually far more. It may take twice as long, and in late failures may never be achieved, as products can fail to clear one of the many critical hurdles at almost any time in their first decade of life. Fortunately, a good product tends to maintain its success for longer than its period of patent-protection.

World sales of agricultural pesticides now amount to about £1500M per annum, the U.K. market being less than 2% of the total. Cotton, maize, fruit and rice form two-thirds of the market, with cereals, potatoes, soya beans, vegetables, sugar beet and tobacco bringing this up to 90% of the total. Market expansion has been about sixfold since 1955, and the growth rate is still forecast to be above industrial average, especially in Western European countries. It varies from 5 to 17%. Of the 160 most important chemicals, about 60 are herbicides, 60 insecticides, 30 fungicides, the rest including fumigants, rodenticides, nematicides, growth regulants.

During 1972, it is estimated that 2 million tonnes of pesticides were manufactured. At an average dosage rate of 1 to 2 kg/ha (1 to 2 lb/acre), the very approximate area treated would be 800 to 1600×10^6 ha (2000 to 4000 million acres). The rate of treatments varies from a few hectares a day, for example in handlancing treatments, to almost 400 ha (1000 acres) a day by aircraft.

Thus, during the past 30 years, the age-old problem of weed, insect and fungus control has been brought into a new perspective. The tools are now largely there, the equipment is available and efficient, and the procedures are well within the understanding of most present-day agricultural workers. The products have steadily become safer, and most governments exert a considerable pressure on firms for the efficacy and safety of the formulated products before they are introduced into the market.

Scale of chemical usage

The extent to which such chemicals are now used in farming practice varies tremendously from country to country and crop to crop. Factors stimulating use of chemicals are the value of the crop, availability of cash, credit or subsidy, high level of agricultural education, intensive crop growing, good extension services, known and visible importance of the pest, good examples from adjacent areas or agricultural leaders, pressures from reduced labour forces or their higher wages, and the demonstration and selling activity of local or international firms.

One would justifiably expect that this country meets such requirements very well, and that Britain should show a very high score in any sprayed area comparisons. This is true as a generalization, but the estimates shown in table 1 made from market surveys in the U.K. give some food for thought. Surveys showing similar variations, far bigger disparities and far greater surprises could be culled from many other countries, including the highly sophisticated countries.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

The first conclusion on crop protection and productivity can thus be drawn: that despite the existence of proven tools and techniques, the opportunity of conserving yields and increasing productivity is not yet being taken fully by growers, in this or indeed any other country. Chemical control methods exist today for most of this country's and the world's major weed, insect and fungal infestations. Admittedly they are imperfect, as are most of man's innovations, but they are not so imperfect as the situations which lead to their not being used, if increased productivity is really wanted.

TABLE 1

crop	problem	infested % area sprayed
wheat	broad leafed weeds	85
	grass weeds	31
barley	broad leafed weeds	85
	grass weeds	24
	fungal diseases	14
oats	broad leafed weeds	85
	grass weeds	4
sugar beet	broad leafed weeds	91
	grass weeds	15
potatoes	broad leafed weeds	65
grassland		< 5 (of total)
crops for stock		25 (of total)

The prevention of pest infiltrations

Many weeds, pests and diseases are annual fixtures in the farming calendar, and they are treated or not treated according to the grower's own decision in this country. Others are swift occasional invasions, dealt with urgently by advisers and growers. The problem of which we must be very careful is that which tends to spread slightly each year, despite the fact that some attempt to control it has been made, and quietly expands at a rate greater than the increasing scale or effectiveness of treatment – a sort of tail-chasing exercise. We have a good example at present in the wild oat problem in Britain; we may have another in blackgrass, and another in cereal diseases. No doubt, others will add themselves to the list in the next two decades. It is a matter of history that in the prevention of communicable diseases of man and animals a difficult and costly decision often has to be made, to scale up measures to prevent spread, accepting short-term urgency and high cost, to produce longer-term gains. The detection of such problems on the basis of annual spread is surely a matter of great importance in the future, especially because agriculture in Europe looks like becoming a very competitive industry overnight.

It would seem logical that the annual quantification of our national weed, pest and disease problems should be ensured, and that these records be considered not for the sake of publication at conferences, but also to ensure that deliberate and if necessary subsidized boosting of control measures for several years be arranged. Such measures must involve close and early collaboration between chemical firms and government.

Such slow-growing problems eroding yields and productivity can all too easily be ignored. The agricultural scouts of the chemical firms do their best, and there are a number of annual discussions between industrial and governmental experts. Nevertheless, we have some examples to refer to where delay has taken us up to some form of brink, and others will arise. The second conclusion to be made is therefore that there should be early diagnosis and early energetic treatment of spreading pest problems within agriculture, especially where new chemicals must be invented, developed and widely used to achieve highly efficient control.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Losses after harvest

The harvested crop in store or in transport is potentially a captive target for infestation by insects, fungi, bacteria, rodents, and biochemical self-destruction. Estimates of direct losses from these factors vary from a few % up to 30 % or even more. A behind the scenes visit to a store, port or market would be educational. The losses are greatest in crops of the developing and hotter countries, but are also demonstrably greater when the mechanical harvesting of sophisticated countries causes more physical damage than hand harvesting. It will probably seem odd to the historians that, while we in this period may be working hard to prevent a 5 to 10 % avoidable loss on the field, we are tending to maintain a somewhat resigned attitude towards losses in storage, bulk packaging and transport. The prevention of such losses can only be partly achieved by chemicals, however. It is only the occasional chemical which is suitable for storage treatments and also demonstrably non-hazardous as a deliberate additive to consumable crops, especially staple crops. Indeed, the chemical industry is nowadays rather hesitant in embarking on the costly and somewhat unpromising task of developing a chemical as a new post-harvest protectant, at least until some more conventional use has been established on which a sound commercial development can be based. These post-harvesting losses still seem to be a drab backcloth against which the more eye-catching but less costly agricultural problems are discussed. There is here further opportunity of increasing end productivity of energetic and sustained chemical and physical measures, many of which are known already.

Soil residents

For some of the world's crops, the nematode is a well known and major pest – tobacco, citrus, bananas, peanuts, pineapple, potatoes. Soil and seed-borne fungi are similarly a notorious problem for some key world crops – rice, cotton, cereals and many other grain and root crops. Soil insects complete the trio. We know that each and all of these are potential crop-destroyers in themselves. It is probable that their effects will be even more important to agricultural productivity as above ground weeds, insects and fungal infestations are better controlled, as seems very likely during the next two decades.

As yet, the chemical industry has not been able to provide, or at least maintain, a supply of suitable new nematicides, or soil and seed fungicides, or soil insecticides. It must also be accepted that such control measures in soil, unless confined to the seed and its immediate surroundings, are apt to be particularly costly. Nevertheless, there is sound reason to pay much greater attention in years to come to the potential losses from soil-living organisms, and to the gain in yields and productivity which could come to some high-value crops from more widely adopted control measures.

The third conclusion may now be drawn: that there are known losses in many stored crops, and probable losses due to soil-living nematodes, fungi and insects, for which the development of control measures using present and future chemicals would be a rewarding source of crop conservation and greater agricultural productivity.

Grass

All the suggestions made so far have shown that there is still a great deal yet to be done nationally and internationally with the chemicals already made available by the chemical industry. It may have been noted that grassland has been referred to very little. That is deliberate,

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

because there is in the pesticide industry a peculiar sort of miasma over grassland, and its weed and pest problems. Such a huge and welcome target for chemical improvement, and yet so relatively unapproachable! Perhaps during the 1970s the agriculturalists can promote grass to the status of a real U.K. crop, so that during the 1980s we can combine to really treat it as such. Most of the tools needed already exist, and others would swiftly follow when the preaching of the gospel came into full voice.

Future possibilities

The aims of the chemical industry at the present time are twofold. First, to encourage the expanding use of the existing chemicals, which they know to have productivity advantages, both short and long term. Secondly, to discover and develop further chemical weapons for use in agriculture, and other constructive activities of man.

The first of these aims has been clarified already; the second takes us into far more speculative areas. It is necessary here to say that most contributory firms have some worries about the future of research and development directed solely towards new chemical pesticides. Inevitably, the cost of a standard effort has increased very sharply in the past decade. The market requirements for a new product increasingly include a performance better than the already good products available from earlier efforts. It is now necessary to fight for a share of one or more markets, or to create a new market.

There is a second latent anxiety, concerning the increasing requirements of regulatory agencies for additional information on new products, their efficacy, safety, and all other properties, in finest detail. It is not the interest in, nor the objectives of such requirements which are disturbing, but the extra delays, costs and expenditure of scientific resources involved before any revenue whatever from sales can be attained. There is a third problem, in that as yet virtually no internationally harmonized scheme of regulatory requirements has arisen from the past three decades of new chemical introductions. Almost every country forms a large or small special problem to itself, as do their official experts. Finally, there is the feeling that very often the governmental decisions made in the last decade to heavily restrict the commercial use of some agriculturally valuable chemicals have been based more upon apprehensive, political or emotional factors than on the scientific or logical approach which industry relies on in its own activities. In this respect, our own country still stands out as having a regulatory control system which has far more to commend it than otherwise. We hope this will continue, and spread; it is a valuable export commodity, not yet sufficiently promoted.

Presuming that there is no significant disenchantment with the investment potential of the agrochemical industry, what is likely to come to the aid of agricultural productivity in the next seventeen years?

We can expect perhaps another 200 new active ingredients to be introduced commercially. Most will be chemically and functionally related to existing chemicals, but in some respect improvements on them. Others will open up new fields of pest control for the first time.

There will be more products consisting of mixtures of two, three or four different pesticides in one product, broadening the range of problems controlled by one treatment.

Formulation techniques will expand, and the past two decades' trend towards reducing water requirements in spraying will continue and increase. New formulation techniques and additives will arise, enhancing activity and possibly reducing dosage rates.

There will be more techniques of combining chemical applications with some other essential process, usually sowing or fertilizer application. Seed dressings will almost certainly become more comprehensive and widespread.

There will be a wider range of pre-sowing or pre-emergence treatments, and more use of granules for that purpose. Methods of using more concentrated granules will be found, to reduce the weight problems. As labour dwindles, band-spraying will tend to decrease, as too slow.

New chemicals seem likely of which one application may do the work of two or more present repeat treatments, particularly in the insecticide and fungicide areas. New insecticides of adequate safety but longer soil persistence than the present organophosphates can logically be expected.

Nematicidal preparations suitable for use by the grower's own application machinery seem inevitable, rather than by contractors.

New chemicals or systems will arise for interrupting life cycles of weeds or pests by chemical treatment just after cropping, or between crops, to reduce the food residue problem from applications to the growing crops.

A wider choice of growth regulants will come forward to induce forward-thinking growers to adopt mechanical harvesting, to avoid labour bottle-necks and ever-increasing wages bills.

Some of the present problem weeds of the tropical countries such as *Cyperus* and *Cynodon* will be controlled as well as we can now control blackgrass. Odd specifics may be stumbled upon for the control of such problems as very deep rooted perennials.

There should be at least one new chemical family of insecticides and of fungicides, each producing several new products of different properties.

There may be one or more new desiccants also, not only for seed crops, but capable of wider use.

We could logically expect one or more new rodenticides, aquatic herbicides, nematicides, and even one molluscicide suitable for agriculture. The possibilities of a new acceptable avicide becoming available for bird-loving countries must be a matter of some doubt.

There will probably be a wider range of non-persistent insecticides and fungicides for the 'cleaning-up' of processed crops shortly before harvesting, thus reducing the crop rejection rate.

There may possibly be some experimental viricides for use initially as tools to probe the market needs of the 1980s or 1990s.

The above possibilities arise fairly logically from trends of recent years, from recent patent lists, and from the believed programmes of research and development in the major companies. They also arise from past evidence that where a technical problem exists, or a market need is obvious, it is only a matter of attention and time that something useful turns up, and with it, other possibilities.

Agriculture is the customer with the problems. There is a lot of extra productivity to be achieved by expanded use of existing materials, and it is this above all other things which will induce more and better chemicals to come forward for the problems of the 1980s.

Conclusions

There is extra productivity to be gained immediately from expanding use of existing chemicals.

There are some 'infiltration' problems which we should detect and then deliberately hit hard and often, at high cost if need be.

Losses in storage are an insult to intelligence.

Soil pest problems need more attention from all of us.

The chemical industry is reflecting on its own future history.

Nevertheless, it is providing a huge scientific effort to back-up agriculture, and there are plenty of future shots to be fired in the war against want.

Discussion

W. R. Boon (*Plant Protection Ltd, Fernhurst, Haslemere, Surrey*). I should like to begin by congratulating Dr Edson on his paper. Indeed, his review has been so wide ranging and complete that it is difficult to add anything further. Nevertheless, there are one or two points which I should like to make or to emphasize.

On the question of the safety of chemicals; safety to the user, to the consumer of treated crops and to the environment I accept it as entirely proper that this should be a matter of concern to governments and to the wider public and that demonstrating that a product can be used safely is properly the responsibility of the manufacturer. Dr Edson mentioned this as a major cost in the discovery and development of a new product. Indeed, it is, but it is only a part of the total cost, which in my judgement, makes the figure of £1M quoted by Dr Edson rather on the low side for a major new product. The total for a minor product is not likely to be very much less. An inevitable corollary is that research has to be aimed at products with a world wide sales potential. The same is even more so for the selection of discoveries for development since the cost of development is normally several times that of discovery. No single market at the present time, with the possible exception of the United States of America, is sufficiently large to justify the research and capital investment which is required before a new product can be introduced. To some extent the same problems face the introduction of products effective against a narrow range of target organisms, a necessary prequisite for integrated control. Nevertheless, some encouraging successes have been achieved, for example in the introduction of insecticides specifically for the control of aphids.

On the purely technical plane, I was rather surprised that Dr Edson did not mention the recent breakthrough in systemic fungicides which, in some cases, are also capable of eradicating an established disease. The protectant fungicides to which we have become accustomed are more like crude disinfectants in the control of human disease than the precise tools of chemotherapy to which we have become accustomed. In my view these new products open up new possibilities in the control of plant diseases as decisively as did the introduction of the sulphonamide drugs into human medicine in the 1930s. I am convinced we shall see further progress in this field.

Although Dr Edson's paper dealt with pest control in its strict sense, this symposium is concerned with the likely pattern of agriculture in the 1980s and I would like to record my firm conviction that systems of growing crops with no mechanical working of the soil, or with a severely reduced amount of tillage but using herbicides for controlling weed competition will become of increasing importance. Progress in the last year or so has been encouraging and there is every indication that such systems are rapidly gaining more widespread acceptance. They have already very largely replaced traditional methods for growing forage *Brassica* crops in this country.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES