Environment and Disease: Ever-growing Concern

Environmentalists tend to be idealists, thinking holistically in terms of natural balance and harmony. As a reaction to modern technological exploitation of Nature, the shibboleth 'back to nature' has re-emerged. However, scientific fact forces us to admit that Nature is not particularly kind or harmonious. For in it, even when left alone, there is harsh competition, resulting in continuing suffering and disease. Death is intrinsic to life, and inevitable, but often comes prematurely and is mostly associated with pain: hence Man's persistent endeavours to control disease and reduce suffering. Much has already been achieved in human disease control, and Man's life-expectancy has increased considerably. However, there is more and more concern about new problems such as AIDS, resurging old plagues such as tuberculosis and cholera, and a host of other newly-recognized or re-emerging diseases. With this in mind, on 11–12 September 1993, a meeting was held at the John Knox Centre on the outskirts of Geneva, Switzerland, to discuss a world-wide Programme for Monitoring Emerging Infectious Diseases (PROMED) of Man, other animals, and plants. The aim of PROMED is to enable effective early response to be made to infectious diseases, to prevent their spread and epidemic development. Meanwhile it is increasingly felt that certain diseases result from Man's own interference with Nature. Thus, some *environmental issues* are due for critical examination.

FAS and WHO

Some 60 health specialists from 35 countries participated in the Geneva meeting, which was co-sponsored by the Federation of American Scientists (FAS) and the nearby World Health Organization (WHO). Initiatives had been taken by FAS, which was founded by scientists who developed the atom bomb when they began to realize what they had done, and consequently intended FAS to act as the conscience of the scientific community. The Federation was also involved in another meeting about to be held in Geneva within the framework of the Biological Weapons Convention, which had been set up in 1972 as a bulwark against one of the weapons of mass-destruction through deliberate provocation of epidemic disease. On this further occasion it was intended to explore avenues for redirecting technology — now that the 'cold war' has come to an end — towards a programme that would help to alleviate disease and suffering world-wide rather than increase these scourges.

Both those meetings reflected an increasing awareness that far more than hitherto needs to be done to prevent the emergence of large-scale epidemics as a consequence of biological warfare, and now even more so as a result of other sorts of human interference in Nature and of natural developments. The PROMED conference was meant as a first step towards a comprehensive global plan for monitoring infectious outbreaks, irrespective of how they are brought about, and for responding at an early stage to prevent their spread and epidemic development. Within the framework of WHO's involvement, emphasis was laid on human ailments, but it was thought wise to include also threats to other animals and to plants.

Threats to Plants

The diseases of crop and other plants can be highly detrimental to human health and well-being, even apart from any health ill-effects of intensive use of pesticides to deal with such diseases. Several plant diseases occur in epidemics that regularly or unpredictably levy their toll by causing great losses of food, feed, and fibre, that are essential for human subsistence. According to the Food and Agriculture Organization of the United Nations (FAO), annually some 30–35% of crop yields are taken by, or do not develop owing to, harmful organisms (pests) such as insects, rodents, Fungi, nematodes, viruses, and weeds, and a further 10–20% are lost during storage. Losses tend to be highest in developing countries, where they often lead to hunger, starvation, predisposition to disease, and to social and economic imbalance.

Especially Viruses

Throughout the Geneva meeting, the most attention was centred on viruses. They are pathogens that 'remain shrouded in mystery', and are commonly the most difficult to deal with. In plants, viruses may dramatically reduce growth or cause premature death, and often do so. Most of them are highly infectious, so that whole crops may be rapidly invaded and totally lost, and wide regions may be involved. There have been many recent dramatic epidemic outbreaks of viruses in crops; for instance, the soil-borne and Fungus-transmitted beet necrotic yellow-vein virus of Sugarbeet (*Beta vulgaris*) in Europe, an increasing number of whitefly-transmitted viruses of vegetables and other crops — particularly in the Americas and the Middle East — the tomato spotted wilt-virus in many types of crop in the Americas and Europe, and the seed-borne and aphid-transmitted zucchini yellow mosaic-virus in cucurbit crops. In the 1980s, areas with irrigated agriculture in the south-western USA had to be declared a 'national disaster loan area' to prevent too many vegetable- and cotton-growers from going bankrupt through disastrous losses from whitefly-borne viruses, and the zucchini virus is now considered 'probably the greatest single threat to the cucurbit industry in California'. The crucial question is, whether such calamities could have been predicted and prevented.

Environmental Conservation, Vol. 21, Nr 2, Summer 1994 — © 1994 The Foundation for Environmental Conservation — Printed in Switzerland

Natural Complexity

The answer to the above question requires an understanding of the ecology of viruses. Plants, when once they are infected with a virus, usually remain infected for the rest of their lives, and there are no practical ways of ridding field-growing plants from infection with chemicals that kill most other pests. The ecology of plant viruses is extremely complex, and comprises various factors, such as:

(1) the *viruses* and their strains;

(2) the *sources of infection* within or outside the crop (including weeds and wild vegetation);

(3) a wide and diverse range of *vectors*, each with a different and often complex ecology of its own;

(4) the *Crops* to be protected; and the

(5) *time and place*, that is, when and where the crops are grown in relation to their source of infection and the availability of vehicles of transmission.

Whether harm and damage will finally result, is largely determined by crop susceptibility and sensitivity, which in turn depend on crop genotype, the ways in which the crops are grown, and on

(6) the *growing conditions*, especially the weather, which also greatly affects vectors.

In this highly complex virus ecology several factors, such as weather and Man *himself*, are capricious. They are hard to measure or predict, and thus are hard to manage effectively.

The Role of Man

The grower himself largely determines the occurrence of virus calamities by choosing the time, place, crop genotype (species and cultivar), and time of planting — also by his overall agro-ecosystems' management and arrangements. These provide opportunities for preventive control of virus diseases in crops, usually comprising a complex of measures to reduce disease incidence. The outcome of the required strategy is often uncertain and practically never permanent. Any change in the cropping system, even when meant for disease- and pest-control, entails the risk of creating new ecological niches for unknown or hitherto unimportant pests to emerge. In fact several, if not most, crop ailments caused by viruses and other pests are *man-engendered*. Viruses and other pests are thus really an intrinsic part of the ever-evolving natural environment at large, and we can never be finished in dealing with such pests decisively.

The role of Man in creating new disease-problems is further aggravated by the scaling-up and internationalization of production, trade, and traffic — including a wide range of plant propagation materials. Actually, movement of viruses in such materials being a major mechanism of international spread of plant virus diseases, they automatically come along in vegetative propagules derived from infected plants, and are increasingly being found to do so in true seeds. Viruses are of particular concern because they are often symptomless in many plant species. They usually come along unnoticed in dormant plant propagation material, and such material cannot usually be disinfected or cured of viruses that may be present. For example, the virus of tristeza of *Citrus* trees is supposed to have moved around the world in scion-wood. Disastrous quick decline and enormous losses were first recorded in Argentina in 1930, and subsequently in other countries in South America, Africa, and other *Citrus*-growing parts of the world, including California, Florida, Spain, and Israel. In Brazil, the disease spread within 12 years to all *Citrus*-producing areas, and an estimated 6 million trees had been destroyed in the São Paulo State alone by 1949, which amounted to 75% of all the orange trees present.

Valuable plant propagation material is prerequisite for crop productivity, and Man is insatiably striving for more and better, and for change. This has led to promiscuity in Man's modern dealing with plant propagation. The transfer of plant propagation material from one place to another is now adding considerably to the natural spread of plant viruses, and is doing so on a global scale. The material may be transferred either as germ-plasm (genetic resource for crop diversification and breeding), breeder's material for multilocational testing, or commercial seed and planting stock, and the movement of all three categories has greatly increased in the last few decades. Consequently, the number of 'AIDS viruses of plants' is rapidly increasing. New problems created by viruses (and other pests) are thus a corollary of agricultural modernization of crops, and viruses follow in the wake of human civilization to the remotest corners of the world.

Conflicting Interests

Awareness of the risks of international spread of plant pests germinated only late during the last century. Developments accelerated after World War II, when global consultations led to the International Plant Protection Convention (IPPC in 1951; revised in 1991). The agreements include provisions to prevent or reduce the international spread of plant pests and to promote their control.

FAO, which acts as the depository of IPPC, now coordinates some sort of a network comprising national and regional plant protection services, such as for health inspection and survey within the respective countries, and for quarantine and health certification of internationally transferred materials. FAO has also set up a World Reporting System, and has developed a computer database for this purpose, although it has been difficult to verify the information which it contains. Such information remains poor in developing countries, and developed countries have often shown reluctance to provide timely and relevant information, because their exports have in

https://doi.org/10.1017/S0376892900024486 Published online by Cambridge University Press

the past been impeded by imposition of quarantine, or by total prohibition of imports of high-risk materials as a non-tariff trade barrier. This is where interests are in conflict.

FAO, together with the International Board for Plant Genetic Resources (IBPGR), has recently set up a Global Programme for the Safe Transfer of Germ-plasm, comprising the development of guidelines for treatment, testing, quarantine, and certification, of germ-plasm moving to and from gene-banks and distributed for breeding. But such efforts to reduce the risks of international spread of pests with germ-plasm are now being counteracted by the present effort to liberalize trade and traffic, including commercial plant propagation materials (GATT negotiations). Such materials are needed for agricultural progress, but large amounts can never go through quarantine, and absolute freedom from pests can never be guaranteed in practice.

Although measures to prevent or delay the geographic spread of viruses and other pests constitute a first line of defence, and must therefore be carefully implemented, we must admit that the risks of international spread are increasing rather than decreasing. This, together with other adverse effects of agricultural modernization, are major mechanisms of the continuing upsurge of old pests and emergence of new ones.

Risk Analysis

How new pest problems will develop is often hard to predict, and the associated risks are difficult to analyse and assess — for a number of reasons such as the following:

(1) Developing countries fall short in studying the *occurrence and distribution* of pests, especially viruses (by proper identification and survey which are of course prerequisite to knowing what we are talking about), and developed countries may show reluctance to provide full information even when they may have it.

(2) When assessing the *risks of movement and entry* into new regions, we must bear in mind that plant viruses cannot move on their own, but do so in:
- plant propagation materials,
- unprocessed plant products for food and feed,
- plant materials brought along by tourists, and
- insect vectors travelling long distances on their own or assisted by Man.

(3) The *risks of establishment* of those viruses that can reach a new place depend upon the availability at that site of:
- susceptible hosts (including wild plants), and of
- vectors (insects, mites, Fungi, nematodes, etc.).

(4) The *risks of subsequent epidemic build-up* depend upon the:
- number of introduced sources,
- vector population density and efficiency, and
- crop susceptibility.

(5) The *risks of eventual crop damage* are finally determined by crop sensitivity.

If none of the susceptible crops is sensitive, no economic damage will result from virus introduction. Then, quarantine or other countermeasures may not be justified. However, when once a pest has settled and perhaps spread unnoticed — possibly in weeds or wild vegetation — it may remain hidden until the later introduction of a sensitive crop or crop cultivar triggers disaster. This now demonstrates the utter difficulty of predicting any international spread of plant viruses, of assessing reliably the risks involved, and of selecting objective criteria to determine which pests need to be kept out of a country by quarantine and other measures. Accordingly, the choice and listing of quarantine pests are often a matter of compromise.

Balance Between Risks and Benefits: a Dilemma?

In fact, most problems with new viruses and other pests in crops are *side-effects of agricultural modernization*, that is, they result from:

(1) continuous change in agro-ecosystems (including the rapid change in genetic make-up of crops) leading continuously to the creation of new ecological niches, and from

(2) large-scale, often long-distance, movement of plant propagation materials.

In its need for progress, agricultural modernization is unstoppable. The competitiveness of modern society entails change and (one hopes) progress, but the risks that are involved are hard to assess. Short-term benefits then instinctively outweigh long-term risks, particularly in this era of privatization and commercialization. Moreover, administrators and politicians are hard to convince of the importance of prevention, the effects of which are mostly invisible and cannot usually be translated into financial terms. Fire extinction is more spectacular than fire prevention, which is why viruses and other pests will continue to come along in the wake of human culture and we will never finish dealing with pests of crops. When dealing with Nature at large, we must realize that risks are intrinsic to life. Without accepting certain risks, there will never be any progress: *'ships are only safe in the harbour, but that is not what ships were made for'*.

Measures

Any measures should therefore be realistic, and compromise is unavoidable. While not setting our expectations too high, we must do our utmost to prevent, or at least delay, the spread of plant pests as a first line of defence, and we must increase alertness with a view to new hazards that are bound to develop. Infrastructures (expertise and facilities) must therefore be improved and maintained to deal adequately with crop pests, as they emerge with continuing agricultural and social change. A Programme for Monitoring Emerging Infectious Diseases would indeed serve such a purpose. Such measures have everything to do with environmental conservation and are highly relevant for sustainable crop health and human health.

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GUEST COMMENT

Trouble in the Cabbage-patch

For more than forty years I have been rearing broods of caterpillars, mainly to try to understand the genetics of colour and pattern-variation in butterflies and moths. From time to time my work has been frustrated by the sudden death of an entire brood, or sometimes of a whole series of broods, and once by the total loss of my laboratory stock; such losses I always attributed to outbreaks of virus infections. When infected, a caterpillar collapses into a liquified mass which hangs from the food-plant — a most unpleasant sight for a caterpillar enthusiast. Curiously, I have never encountered evidence of virus-induced mass mortality in wild caterpillars, although I have occasionally found a solitary caterpillar that showed symptoms of having succumbed to such infection.

For more than fifty years there has been a rapidly-growing interest in the use of viruses as substitutes for, or additions to, chemical insecticides to control insect pests — chiefly on the grounds that such control is biological and therefore potentially less harmful to the environment than Man-made insecticides. Attention has been focused on one group of viruses, the Baculoviruses (BVs) which affect caterpillars, and especially on a group of BVs called nuclear polyhedrosis viruses (NPVs). Trials and applications indicate that laboratory-produced NPVs are an effective method of destroying caterpillar pests of forest trees and crop plants. NPVs and other microbial insecticides now comprise up to 2% of the insecticide market (Cory, 1994). This figure is likely to increase as research produces new and better strains of viruses.

Dangers of Genetic Manipulation

Recent research has concentrated on genetically 'engineered' NPVs. For example, a scorpion-venom gene has been transferred to the *Autographa californica** NPV (AcNPV) which, it is claimed, makes the virus more effective; the virus is 'turbo-charged', some reports claim. In March 1994, the Institute of Virology, Oxford, announced in a local newspaper (*Oxford Mail*, 5 March 1994) a proposal to go ahead with a trial of this genetically engineered AcNPV on caterpillars feeding on cabbages grown in an experimental plot. The site chosen is a field within view of Oxford University's Wytham Estate, where much fundamental ecological research has been (and still is being) conducted — including research on caterpillars and caterpillar-feeding birds. Permission to perform such an experiment needs to be given by the appropriate office of the British Government, which seeks advice from the Advisory Committee on Releases to the Environment (ACRE), an independent body that evaluates the pros and cons of experiments of this nature.

A local resident, Dr G.D.W. Smith, became concerned about the possible dangers to wildlife which might be posed by the proposed experiment if something should go wrong and the virus escape to the wild, and wrote to the Biotechnology Unit (the Government department concerned) to express his fears. A letter of protest was also sent to ACRE. However, permission for the experiment to proceed was given on 12 April 1994. Soon afterwards, national newspapers were alerted and took up the story. There was plenty of scope for the headline writers: for example, 'Scorpion's venom fuels genetics dispute' and 'Scientists warn of scorpion venom test' (*The Independent*, 17 May 1994). As a result, the experiment was postponed for fourteen days, offering more scope for the newspapers: 'Testing of caterpillar death virus halted' (*The Times*, 26 May 1994) and 'Objectors win delay of scorpion virus trial' (*The Independent*, 26 May 1994). Nevertheless, ACRE reconsidered the proposal, and on 8 June 1994 the Government gave permission for the Institute of Virology to proceed with the experiment.

* A North American moth of which the caterpillars were an early source of the virus. Insect viruses are often named from their hosts, hence this 'AcNPV'.