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IMPORTANCE OF ECOLOGICAL STUDIES IN PLANT VIRUS RESEARCH

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Abstract

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With increasing expertise and facilities to detect and recognize viruses, there is an increasing awareness of the limiting role of viruses in crop production, both quantitatively and qualitatively. Moreover, modern farming systems and genetic crop constitution tend to make crops more prone to epidemic attack. Since viruses in crops cannot be directly controlled with chemical means, countermeasures are preventive only. This necessitates profound knowledge of the complicated ecology of viruses that are of direct or potential economic importance to crops. However, with continuously changing agro-ecosystems, including the introduction of resistant cultivars, new problems by viruses, and other pathogens and pests are bound to continuing arise. Modern agriculture thus requires permanent support by crop protection research, including virology, and emphasizing ecological aspects.

Additional key word: ecology, plant viruses, preventive measures.

Introduction

Dealing with plant viruses at a meeting of a society for plant protection necessitates concentration on these pathogens in terms of what can be done against them. Unfortunately so far, there are no ways of curing plants from virus disease, e.g. with chemical or physical means, once they are infected and most probably will not be in the near future. Thus, practicable control of such diseases is preventive only. We must therefore know (i) where the causal agents come from, what their sources of infection are and how these can be removed or avoided, (ii) how the viruses spread, what their vectors are and how these can be controlled or avoided, and (iii) what determines crop vulnerability to the viruses and how resistance can be improved. Hence, profound knowledge of the ecology of viruses that cause economic damage is essential.

I have talked and written on this highly important aspect of applied plant virus research on several other occasions. For details and further literature, let me refer to the publications concerned (2, 3, 4, 5) and to Plumb and Thresh (7). With a view to the limited time and space available, I will now confine myself to the main lines of thought. Emphasis will be on the effect of human interference with nature, for instance through man's agro-ecosystems, in provoking virus diseases and in preventing them to a certain extent.

Economic Importance of Viruses

First some information is required on why we have to deal with plant viruses. It is increasingly obvious that they play an important role in agriculture. They do so through their often dramatic effect on individual plants and through their high infectivity and rapid epidemic spread in crops, thus considerably reducing economic output in terms of yield and quality.

Virus infection causes variegation, yellowing, necrosis, stunting and malformation, which often greatly impair plant growth. Most of the symptoms other than variegation are not generally recognized as caused by viruses. So the role of viruses in crops is not yet fully appreciated. This holds especially for viruses that are so-called symptomless or latent in plants, but may still reduce plant vigour and greatly increase vulnerability to other pathogens, to drought and to winter injury. Viruses may also reduce quality of the harvested product by reducing keepability or taste and texture.

Many viruses are so highly infectious that rates of infection in single crops may rise from zero to practically 100, leading to total crop failure, sometimes in two months time. If a virus becomes established in an agricultural or natural environment, virus epidemics may also build up rapidly in large areas in a number of years, destroying the possibilities of growing certain crops in those areas.

Multifactorial Ecology

Occurrence of an epidemic raises a number of questions. We must know (i) which virus is causing the disease, (ii) where it comes from, (iii) how it moves about, and (iv) why the crop is vulnerable to infection. In short, this is virus ecology. It is more complicated than a simple disease triangle, consisting of pathogen, host and environment, because there are many different vectors that act as vehicles of spread and that have complicated ecologies themselves . The environment, including the cropping systems, has a diverse effect both on vector behaviour and crop vulnerability. It comprises important (wild) sources of infection too.

Thus, the ecology of viruses is multifactorial. It is composed of seven main factors or groups of factors. Major ones are (i) the **viruses** that come from various (ii) **sources of infection** do so with the help of a wide range of (iii) biotic and abiotic **vectors**, and threaten (iv) the **crops** that must be protected. They are all greatly influenced by (v) **environmental** and **cultural** conditions. Wether infection and spread from source to target occurs also depends on (vi) **time** and (vii) **space** (or distance).

Many of the factors listed greatly depend on man himself as will soon be shown in further detail. So bear in mind that virus diseases usually result from human interference with nature and must therefore be remedied, if possible, by adjusting existing agro-ecosystems, and can be prevented by including preventive or phytosanitary measures in such systems.

Viruses

We must first know about the viruses because they all differ in their ecology. So far, some 700 to 800 plant viruses have been to some degree characterized and named. With the advent of molecular biology and physico-chemical characterization, order is emerging from chaos, and with modern physico-chemical and serological techniques (including electron microscopy, cDNA hybridization and enzyme-linked immunosorbent assay, ELISA) viruses can be detected and recognized with increasing ease and reliability. However, we must constantly be on the alert for new viruses, particularly in regions or countries where virus research is just beginning. Moreover, in regions where they hitherto did not occur, viruses are increasingly showing up through natural spread or introduction by trade in plant material, general traffic and tourism. Biological tests (e.g. with indicator plants) are still indispensable to detect new viruses or new strains of known ones. We must know about strains because of their possible ecological differences, particularly for their genetic interaction with host cultivars. Hence, reliable virus detection and recognition as a basis for etiological diagnosis is prerequisite to the study of ecology and to eventual control.

Sources of Infection

A continuing cycle of infection and epidemic build-up are simplest with perennial crops or overlap between old and new crops. For annual or short-duration crops, they are simplest with year-round cultivation in mild or tropical climates, or with irrigation and planting of winterhardy cultivars during the winter. With crops grown as annuals, as are many root crops (beet and carrots), perennation of virus may be in vegetative planting material replanted next season for the production of seed.

Several viruses may infect related or totally different crops and may thus move from one crop species to another. Well known is the impact of several viruses in perennial clovers (*Trifolium* spp.) on infection of annual legumes, such as pea, faba bean and *Phaseolus* bean. Bean yellow mosaic virus is one of those viruses. It is also prevalent in gladiolus plants, often without causing symptoms. Nearby susceptible bean crops are known to suffer often from infection.

Other examples of viruses getting from one crop species to another and their long-distance spread by aphids in a persistent manner is of luteoviruses. In several regions, including the Middle East, crops of lucerne *(Medicago sativa)* often harbour bean leafroll virus, and mostly do so without symptom. The virus then causes serious yellowing, leaf roll, stunting, and sometimes premature death in several annual legumes, including chickpea, cowpea, fababean, pea and *Phaseolus* bean. A similar example is of the related barley yellow dwarf virus possibly occuring worldwide, including the Middle East and North Africa, in barley, oats and some other cereals. It is prevalent, though usually latent, in pasture or wild grasses.

Another luteovirus of worldwide occurrence, but with much wider host range, including several arable and vegetable crops such as beet, lettuce and turnips, is beet western yellows virus. This virus infects many weeds, in these not causing obvious symptoms because of natural selection for resistance or tolerance in genetically heterozygous populations. Thus, weeds and indigenous vegetation are known to harbour many viruses without suffering from them and without showing their presence. Such viruses may show up when susceptible genotypes are grown in uniform stands nearby. This is how swollen shoot is supposed to have become disastrous in *Theobroma cacao* in West Africa after introduction from South America, by spread by mealybugs from indigenous tree species of Bombacaceae and Sterculiaceae.

Most efficient major sources of infection within a crop at the onset of crop development are plants infected from vegetative planting material or from seeds. Since viruses generally go systemic in their hosts, any type of vegetative propagation material from virus-infected plants is also infected. That is why vegetative propagation of crops, including citrus and other fruit-trees, in the past often led to complete infection of such crops.

For long, viruses were supposed not to pass through true seed to sexual offspring of plants or to do so exceptionally, as for bean common mosaic virus, lettuce mosaic virus and soybean mosaic virus. In recent years, the number of viruses found to be seed-transmitted in at least some of their hosts is steadily increasing though they often occur in very low proportions of the seed from infected mother plants. Virus-infected seeds may act as major means of virus perennation, and infected seedlings act as efficient sources of inoculum for further spread within and from newly sown crops. A high proportion of seed-transmitted viruses is readily further spread by aphids in a non-persistent manner. Some others are spread by leaf beetles and a whitefly. Several soil-borne viruses are transmitted through high proportions of seeds of crops and wild plants, and are further spread by nematodes.

Vectors

This paper does not allow going into detail about the biology of the wide range of biotic vectors of plant viruses and the interesting mechanisms of their transmission. Several viruses have intimate relationship with their vectors; some even multiply in them. Transmission by vectors is usually highly specific and as a rule viruses transmitted by one type of vector are not transmitted by other types. This together with the complicated life cycle and behaviour makes aphids, leafhoppers, mealybugs, mites, whiteflies, nematodes and soil-inhabiting fungi intricate and intriguing components in the ecology of viruses. Mention has already been made of the impact of the type of persistence in the vector on distance of transport by the vector. Non-persistent transmission is usually over short distances of up to some hundred metres only and rapidly decreases with distance. Long-distance dissemination may be for hundreds of kilometres when vectors persistently carrying the virus are transported by high-altitude jet winds.

Recently, there is increasing concern about virus transmission by fungi, transmission to plants by their water-dependent zoospores, long-term perennation and long-distance dissemination of the viruses concerned in their highly persistent resting spores, such as beet rhizomania or necrotic yellow vein virus transmitted by *Polymyxa betae* in Italy.Japan and Western Europe, and of some cereal viruses, including barley yellow mosaic virus transmitted by *P. graminis.*

Seeds and biotic vectors may be further spread by wind (as already mentioned for insects) and water, and there is an increasing interest in the role of irrigation and river water in the spread of virus-containing fungal spores and of some viruses that do not need the mediation of a biotic vector, such as cucumber green mottle mosaic virus and tomato bushy stunt virus.

Man himself had turned out to be of utmost importance as a vector. Some viruses, such as tomato mosaic virus., cucumber green mottle mosaic virus, tobacco necrosis virus, bean mild mottle virus and potato virus X, are readily transferred on hands and tools, and sometimes on clothes of labourers working in crops. Virus-containing seeds and fungal resting spores may be transferred in soil, and on planting material, farm implements and vehicles. Much more far-reaching, however, is man's distribution of viruses in seeds and vegetative propragation material. But for a few viruses that superficially contaminate seeds or are present in seed coats (and perisperm) only, such viruses cannot be eliminated from the propagation material, and seeds that contain the viruses in their embryos usually keep on doing so as long as the seeds remain viable.

Crops and their Ecosystems

The ultimate question is whether a certain crop at a given infection pressure will contract disease and will suffer from infection. This depends on its vulnerability (=susceptibility + sensitivity) which is genotypically determined but phenotypically modified by natural and cultural (=cropping) conditions, Since plants infected from outside sources in due course act as secondary within-crop sources of further spread, the factors listed affect plants as individuals and as a population. This means that in more resistant crops or cultivars, virus build-up in individual plants as well as epidemic build-up in the crop as a whole will be slower than in a more susceptible crop or cultivar. Thus, knowledge of crop or cultivar vulnerability to viruses prevalent in a certain area is highly necessary, and the same holds for the possible effect of growing conditions on disease severity and incidence. The method of cropping too is bound to have a great bearing upon vector incidence and behaviour, further contributing to the cruciality of growers' decisions in determining final crop loss.

The introduction of new genotypes and their encounter with endemic viruses may lead to severe disease outbreaks, if the new introductions are genetically vulnerable, especially when planted uniformly and over large areas, as compared with landraces in a traditionally diverse agriculture. New cultivars, even when resistant to certain pathogens including viruses, may turn out to be more prone to other viruses that create new problems in them sooner or later, as did rice yellow mottle virus in new cultivars of rice introduced into Africa.

New and more uniform crops may also stimulate certain vectors to propagate more abundantly, as did the whitefly, *Bemisia tabaci* in soybean ın Brazil, in turn leading to a tremendous increase in whitefly-vectored golden yellow mosaics in other legumes. Irrigation in the open, and nutrient-film technique in greenhouses may enormously favour virus diseases like rhizomania in beet crops and big vein of lettuce, spread by aquatic zoospores of *Polymyxa graminis* and *Olpidium brassicae,* respectively. Year-round cultivation, with the advent of cold-resistant cultivars for cultivation in winter and application of irrigation for continuing cultivation during summer in dry areas, may lead to a continuous infection cycle for viruses that depend only on one crop species. Intensified use of perennial leguminous fodder and soil covercrops to replace fallow cropping may lead to severely intensified attack of annual legumes by a range of viruses, including bean leafroll virus in pea, fababean and chickpea.

Epidemiology

The foregoing has shown that the effect of climatic and other environmental conditions on virus ecology is multifarious. This effect is especially on the crop as a virus host, on the sources of infection, and very much so on the vectors. That is why, especially in regions like Western Europe with capricious climates, epidemic build-up is hard to estimate and predict, and why epidemiology of virus diseases, meant to assist in deciding whether and when to interfere, is lagging behind that of crop attack by fungi and insects.

However there are factors or parameters that may be measured. One of the problems in describing and analysing the epidemic build-up in crops is that the crops act as target of infection and then contribute to epidemic build-up as major source of inoculum, once the epidemic started within the crop itself.

The infection pressure exerted on the crop depends on inoculum pressure and vector pressure. Inoculum pressure is determined by the nature of the virus (i.e. its aggressiveness = ability to multiply in plants), and the number and quality (i.e. susceptibility = ability to support or assist virus multiplication) of the sources of infection, and on the distance between source and target. Vector pressure is determined by the number and mobility, including wind direction, of the vector species, by the type of virus-vector relationship, and by transmission efficiency.

Wether infection pressure builds up within a crop and to what extent leading to epidemic attack finally depends on crop susceptibility (or its lack of resistance). Whether damage finally results and how much is determined by crop sensitivity (= ability to react with symtoms and their severity), and by the time during crop development when plants became infected (2).

Knowledge of all these factors, though still hard to measure, and usually more empirical than scientific, may help in defining whether measures must be taken and when.

Control

The wide range of preventive measures of control, greatly depending upon the virus to be controlled, can only be mentioned briefly here.

Avoidance or removal of sources of infection means, for instance, the use of certified or, if possible, completely pathogen-free propagation material, removal of infected crop plants, and weed control and avoidance of other nearby infected crops or wild vegetation. Prevention of diminishment of spread means production and distribution of certified seed, quarantine at national ports of entry, vector control or avoidance of the vector by cultivation in a vector-free period, space or area. Improvement of crop resistance usually means the choice of disease-resistant (= at least tolerant, but preferably virus resistant) crops or cultivars, and breeding for resistance if no resistant cultivars are yet available.

Host resistance often is the only way of control, for instance, when the sources of infection are abundant and hard to remove or avoid, and when vector pressure is high and transmission (e.g. by aphids) is non-presistent. However when resistance is absent or is partial, resulting in only delayed crop attack, then other ways of control may be preferable or a combination of methods, such as those proposed for the control of cucumber mosaic virus in melon in southern France (6).

Several methods of control may have adverse effects as well. Even the introduction of resistant cultivars may mean inadvertent introduction of susceptibility to viruses and other pathogens that were previously unimportant. Breeding or selection for resistance to vectors has sometimes led to increased incidence of infection by viruses that are transmitted by aphids in non-presistent manner because these are more restless and make shorter probes on cultivars less palatable to the aphids (1). Furthermore, breeding for whatever purpose requires germplasm often originating from wild sources. With such material and through breeding programmes, new viruses have often been introduced and spread, despite increasing efforts to improve the safe global transfer of gene resources.

Conclusions

A certain number of the preventive control measures can be taken by the grower himself, but most measures must be taken outside the crop and farm. Moreover, what is done in the crop or neglected there may have a bearing on the crops of neighbours or more distant farmers. In particular, crops grown for propagation material have an influence on farmers in a wide radius. Thus, public interests are at stake, and this explains the involvement of government and international organizations for legislation, quarantine, eradication and certification, and for education and extension. Governments are also responsible for research because so much is still not known about viruses.

Applied plant virus research comprises (i) the surveying of crops for viruses and the identification of the viruses and their strains. (ii) detailed study of the ecology of viruses of actual and potential economic importance, and (iii) the development of control strategies. Such work cannot avoid some service work such as diagnosis, antisera production and support to breeding for resistance by the development of screening methods and by provision of reliable inoculum, and in several countries the actual breeding for resistance itself.

Finally we must be prepared that this will be a continuing process because new problems appear all the time.

ملخص موسع

بوس، لوت. 1986 . أهمية الدراسات البيئية في بحوث أمراض النباتات الفيروسية . مجلة وقاية النبات العربية 4 : 70 - 75

عند الحديث عن الأمراض الفيروسية فإن أول ما يتبادر إلى ذهن المهتم هو كيفية مكافحتها. غير أنه للأسف لا يمكن مكافحتها حتى الوقت الحاضر إلا بالطرق الوقائية التي تتطلب معرفة دقيقة بالعلاقات البيئية لهذه الأمراض وخاصة

تلك التي تسبب خسائر اقتصادية كبيرة. وهذه العلاقات البيئية متداخلة بعضها ببعض؛ فإذا ما نظرنا إلى وباء ما بهدف معرفة مدى الخسارة الاقتصادية الناجمة عنه، وكيفية مكافحته وجب علينا الاجابة على التساؤلات التالية: 1) ما هو بالتحديد المرض الفيروسي الذي يسبب هذا الوباء، 2) من أين تأتي الاصابة 3) كيف ينتقل و4) ما الذي يتحكم بحساسية النبات للاصابة بالفيروس، وهل من الممكن زيادة مقاومة النبات له أم لا. كل ذلك يدفعنا لدراسة علم البيئة للأمراض الفيروسية الذي هو أكثر تعقيداً من علم البيئة للأمراض الأخرى (فطرية كانت أو بكتيرية). ذلك أن العامل الاضافي عند دراسة الأمراض الفيروسية هو الحشرات الناقلة التي تلعب دوراً أساسياً في عملية انتشار المرض ولها بالطبع انظمتها البيئية المختلفة والمتشعبة.

يتراوح عدد الفيروسات الممرضة للنبات والمصنفة حتى الآن من 700 - 800 فيروس نتيجة لتقدم العلوم الطبيعية وطرق الكشف عن الفيروسات، بحيث أصبحت عملية تحديد ماهية الفيروس أسهل وأدق. إلا أنه يجب التنبيه دوماً إلى وجود أنواع جديدة وخاصة في الأماكن التي بدأت فيها الأبحاث على الأمراض الفيروسية حديثاً، ففي البلدان التي ينعدم فيها الحجر الزراعي فإن مثل هذه الاحتمالات تزداد. إلا أنه تحت هذه الظروف لا يزال استعمال النبات الدال هو الطريقة الوحيدة للكشف عن ماهية الفيروسات والسلالات الجديدة منها. أن عملية تحديد الفيروسات الموجودة في منطقة معينة والسلالات المختلفة منها تشكل الخطوة الأولى في الدراسة البيئية للفيروسات تمهيداً لمكافحتها.

أما مصادر العدوى فإنها تختلف باختلاف الأنواع النباتية، ففي النباتات المعمرة يكون التكاثر الوبائي للفيروس اسهل مما لو كان في النباتات الحولية نظراً لوجود حلقة دائمة للاصابة في النباتات المعمرة. ومعظم الفيروسات غير متخصصة إذ لا تصيب نوعاً أو أنواعاً نباتية متقاربة بل وقد تتعداها إلى نباتات من عائلات مختلفة. وهذه الخاصية تسهل على الفيروسات الانتقال بحرية وباعطائها فرصة كبيرة للبقاء بشكل متواصل. وكمثال على ذلك فيروس التفاف أوراق الفول الذي ينتشر في كثير من البلدان، ومن ضمنها الشرق الأوسط حيث يتراكم في نبات الفصة دون أن يؤدي إلى أية أعراض مرضية عليه، ثم ينتقل منه بواسطة حشرات المن إلى نباتات حولية أخرى مثل الحمص والبازلاء واللوبياء والفاصولياء والفول، حيث يؤدي إلى اصفرار وتجعد في الأوراق وتقزّم ثم الموت المبكر لكثير من النباتات المصابة. وتعتبر الأجزاء النباتية المستعملة في التكاثر الخضري وكذلك البذور من أهم مصادر العدوى وأكثرها فعالية في اصابة النباتات بالفيروس، مباشرة بعد الزراعة. وهذه المصادر يمكن أن تلعب دوراً كبيراً في عملية استمرار المرض عبر السنين أو حتى في انتشاره خلال الموسم الزراعي الواحد حيث تكون هي المصدر الأول للعدوى ومنها ينتقل المرض بسرعة إلى النباتات السليمة الأخرى. هذا ومن الجدير بالذكر أن أكثر الأمراض الفيروسية التي تنتقل بالبذور فإنها تنتقل أيضاً بواسطة الحشرات (من، نطاطات، ذباب أبيض، خنافس. . . الخ) اذ تنشأ في بعض الأحيان علاقة حميمة بين الفيروسات والحشرات الناقلة بحيث يتم تكاثر الفيروس في داخل أجسامها. وبهذه الطريقة تنقل الحشرات الفيروس إلى مسافات بعيدة وبطريقة مستمرة. ونظراً لدورة الحياة المعقدة تلك السلوك الغريب للفيروسات فإن الحشرات الناقلة تشكل عنصراً مهماً في الدراسة البيئية للأمراض الفيروسية. ويجب التنويه هنا إلى ان الانسان نفسه يلعب دوراً رئيسياً في الكثير من تلك الأمراض أيضاً، مثل فيروس موزاييك البندورة الذي ينتقل باليد والأدوات المستعملة في الزراعة. وقد يكون الانسان ناقلاً غير مباشر أيضاً عندما يوزع بذوراً حاملة للأمراض الفيروسية الى مختلف البلدان لزراعتها.

ونظراً إلى طبيعة النبات والعوامل البيئية المحيطة فإن أهم سؤال يطرح نفسه هو ما إذا كان صنف معين، بعد اجراء عدوى له يتأثر بالمرض أو حساساً للاصابة به ام لا. لأن هذه الصفات تعتمد على التراكيب الوراثية للنبات والتي تتأثر بالظروف المناخية والأساليب الزراعية المتبعة. ان ادخال اصناف جديدة متجانسة إلى مناطق لم تكن مزروعة فيها من قبل يمكن أن يؤدي إلى: أ) تفاعلها مع الفيروسات المستوطنة وبالتالي زيادة انتشار المرض، ب) زيادة نسبة الاصابة إذا ما زرعت تلك الأصناف لوحدها في مساحات كبيرة وجـ) زيادة حساسيتها لمجموعة أخرى من الفيروسات التي لم تكن مهمة من قبل. كما ان الزراعة المتواصلة لمحصول واحد في الحقل أو في البيوت البلاستيكية مثلاً على مدار السنة يؤدي إلى تواجد مصدر دائم للعدوى مما يزيد من شدة الاصابة.

إن أهم الطرق الوقائية المتبعة حالياً في مكافحة الأمراض الفيروسية هي: 1) التخلص من مصادر الاصابة وذلك باستعمال بذور خالية من الأمراض الفيروسية، ومكافحة الأعشاب الضارة التي تلعب دوراً مهماً في استمرارية المرض خلال السنة 2) منع أو تقليل انتشار المرض وذلك بانتاج وتوزيع بذور أو شتلات سليمة مع إجراء حجر صحي جيد على حدود البلدان من قبل المؤسسات الرسمية، ومكافحة الحشرات الناقلة أو تجنب وجودها وذلك باتباع مواعيد زراعة تساعد على الهروب من الاصابة، وأخيراً 3) تحسين مقاومة النبات للمرض وذلك باستعمال أصناف مقاومة، وفي حال عدم توفرها العمل على استنباط أصناف مقاومة. كما أنه من المفيد هنا دمج عدة طرق معاً للمكافحة، بحيث يمكن تجنب سلبيات استعمال طريقة واحدة، ومع التنبيه مرة ثانية

إلى أنه عند ادخال صنف مقاوم لمرض معين في منطقة ما قد يؤدي ذلك إلى ظهور حساسية عند ذلك الصنف إلى عدة أمراض أخرى لم تكن ذات أهمية سابقاً مما يسبب بالتالي إلى ظهور مشكلة لم تكن موجودة قبلاً وهذا يتطلب متابعة متواصلة من قبل المختصين في هذا العلم.

كلمات مفتاحية : بيئة الفيروسات، الطرق الوقائية، فيروسات النبات.

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