Use of Non-Chemical Alternatives to Synthetic Pesticides in Maintaining Plant Health in a Clonally Propagated Crop: Potato

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Abstract

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Aphid transmitted viruses are the primary cause of potato seed lots being rejected or downgraded for recertification. Farmers tend to consider insecticides their primary defense against current season spread of potato viruses in seed potatoes, but their use is of inconsistent benefit. Insecticides can interrupt PLRV spread from within field sources because of the extended post-acquisition latent period of this persistently transmitted virus. However, winged viruliferous aphids generally are not killed quickly enough to prevent PLRV spread even when aphidicidal residues are present. All other aphid-transmitted potato viruses are transmitted non-persistently and can be acquired and transmitted in feeding probes of seconds, making insecticides of little benefit. Non-chemical control alternatives to virus control include strategies to reduce infection exposure, e.g., limited generation seed increase, summer field inspections and rouging to eliminate within field sources of virus inoculums, off-season grow outs of representative sub-samples of seed lots and decertification of those above virus incidence thresholds, spatial isolation of seed production from virus sources and severe vector pressure, temporal avoidance of vectors including early vine kill and environmental manipulations to reduce vector numbers. Floating row covers can be used to protect early generation seed increase. Planting crop borders around seed fields, 3-m wide is sufficient, and achieving uniform stands to minimize within field plant apparentcy to winged aphids can effectively limit vector colonization. Use of agricultural oils can limit spread of non-persistent viruses such as PVY, while insecticide applications targeted to field margins at the onset of colonization events can greatly reduce insecticide use and costs, while preserving natural enemies.

Key words: Virus-free propagation, potato seed, certification, aphid-transmitted viruses.

Introduction

Potato (*Solanum tuberosum*) is clonally propagated. Thus, access to high quality, disease-free seed potatoes, has been described as 'the single most important integrated pest management practice available to potato growers' (5) and is essential for successful commercial production.

Aphid-transmitted viruses are among the most important tuber-borne diseases of potato. Management of insect-vectored pathogens represents a level of complexity beyond that of the classic disease triad of susceptible host, viable inoculum, and favorable environment. The additional complication is the vector that must acquire and transmit the pathogen to enable progression of the disease. Approaches to management of virus spread in potato can be categorized as preventive or therapeutic (9). Prevention focuses on reducing inoculum, a primary objective of all seed potato certification programmes, with therapeutic action focused on vector reduction.

Potato viruses

At least 13 potato viruses are transmitted by aphids, the most important of these being *Potato leafroll virus* (PLRV, Genus *Polerovirus*, Family *Luteoviridae*) and *Potato virus Y* (PVY = mosaic, Genus *Potyvirus*, Family *Potyviridae*). Aphid-transmitted viruses differ in how they are acquired, whether they circulate within the body of the vector, how they are transmitted to healthy plants, and how long a vector remains infective following virus acquisition. These characteristics have considerable bearing on the effectiveness of various control tactics.

PLRV is persistently transmitted. In secondarily infected plants (i.e., plants grown from infected tubers), PLRV is found almost exclusively in phloem tissues. Thus, only aphids that colonize potato, and not all of these, can acquire PLRV. Once PLRV is acquired by a vector, the virus circulates through the aphid's body and after a latent period of ~24-36 h can be transmitted for the rest of the life of the vector, even after molts. *Myzus persicae* (green peach aphid) is the most efficient, cosmopolitan, and commonly abundant vector of PLRV (10).

All other aphid-transmitted potato viruses are stylet-borne and transmitted nonpersistently. The nonpersistently transmitted stylet-borne viruses are relatively stable and reach high titers in epidermal and subepidermal plant cells. More than 50 species of aphids are capable of transmitting PVY, including many species that cannot colonize potato.

Acquisition and inoculation of PVY and other non-persistently transmitted viruses can occur in probes of just a few seconds duration. The nonpersistently transmitted viruses are only transmitted for a few feeding probes following acquisition and never following a molt.

Chemical control

Among reported successes of controlling virus spread by use of insecticides (all crops and insect vectors), 94 of 119 cases involved persistent and semi-persistent viruses (6). Most of the failures, 32 of 48 cases, involved nonpersistent viruses. Even when aphicidal residues are present, viruliferous alatae generally are not killed quickly enough to prevent virus transmission.

Insecticide use can reduce spread of PLRV, but is seldom of any benefit in preventing spread of nonpersistently transmitted viruses. PLRV spread from within field foci can be suppressed by insecticides because of the extended post-acquisition latent period required before an aphid is able to transmit, but is much less effective if the virus is being moved from outside sources by winged, viruliferous aphids. Insecticides are almost never of any benefit in preventing spread of PVY (8).

Nonchemical control

Cultural control methods often are among the most effective and inexpensive of virus/vector control measures that growers can implement. These practices are usually not complicated, but require applying knowledge of vector biology and ecology. What follows is a description of several non-chemical or reduced chemical use approaches we have used to control the spread of aphid-transmitted viruses in seed potato. Vector suppression can never be totally successful so the primary line of defense against virus spread must be to minimize exposure of the seed potato crop to virus inoculum.

Seed certification

Assuring cultivar integrity is the primary objective of seed potato certification programs. Seed potato lots can be downgraded or rejected for recertification for a myriad of causes, but aphid transmitted potato viruses far exceed all others. Most seed potato certification programs employ a limited generation production system (4). Typical production systems permit field increase for 5 to 8 generations. In modern practice, seed potato increase is initiated with tissue culture derived seedlings ELISA tested to assure freedom from viruses. Seed potato increase fields are inspected periodically during the growing season by seed certification personnel and a representative sample of harvested tubers is indexed for virus or other defects. Virus tolerances for recertification are stringent for all generations (typically <0.0-1.0% total virus), but usually relaxed incrementally with successive generations of increase.

In recent years, virus management in seed potato production has proven increasingly challenging worldwide. Suggested as possible contributing causes include emergence of new virus strains that are difficult to detect visually, increasing use of cultivars that visually are essentially asymptomatic, insecticide resistance in aphid vectors and pesticide induced vector outbreaks, changing vector associations and even global warming.

Spatial isolation

Ideally, seed potato increase should occur in areas well isolated from ware production. To achieve this isolation, many U.S. states and Canadian provinces have established seed farms or designated geographic areas where potato production is limited to seed. In most countries, there is little isolation of late-generation seed and commercial production. The question is not what degree of isolation would be optimal, but what is the minimum separation required to reduce to an acceptable level the risk of virus spread from sources of virus inoculum or crops that produce large vector populations?

Because PLRV is transmitted in a persistently much greater isolation distances are needed to limit spread of this virus than are needed to limit PVY spread. Based on vector flight behavior as evidenced by captures in suction traps in eastern Idaho, it was suggested 400 m to 5 km could provide effective isolation from known PVY sources, but that 30 km or more might be required for isolation from PLRV sources. In England, minimum separation of 800 m is recommended from potential sources of PVY, but in Denmark, a distance of just 40 m was shown to reduce spread of PVY. Seed growers generally have limited flexibility in locating their seed fields, thus other cultural control methods and vector management assume greater importance.

Isolation can also be achieved by modifying planting or harvesting dates. Early planting and haulm destruction ("vine-kill") dates have been recognized as an effective method of maintaining the health of elite seed stock. Early planting can be a useful strategy if the principal vector species do not begin colonization until late in the growing season. The more advanced the crop growth stage at the time of inoculation, the less likely daughter tubers will become infected.

Physical removal (rouging) of plants grown from virus-infected tubers can be a useful management tactic. Roguing is only practical when the initial incidence of virus infection is low (<1-2%) and if the field is small enough that every plant can be inspected several times during the growing season. Roguing should begin as soon as symptoms of secondary infection can be seen, typically when plants are 15-20 cm tall.

Protective barriers

Polymer webs can provide a high degree of protection against aphid-transmitted viruses, but the cost and inconvenience of row covers limit their application to seed potato fields of very high value and small size. Barrier (border) crops are more widely adaptable than mulches or floating row covers; they are easier to install and keep in place, and do not lose effectiveness due to weathering or when the canopy closes. Barrier crops should have a fallow outside border with no gap between the barrier crop and the potato field, since winged aphids tend to alight at the interface of fallow ground and green crop. If immigrating alatae carrying PVY feed first on the border crop, they will probably lose their virus inoculum before moving into the potatoes. Barrier crops need be only a few metres wide to be effective. In Lower Saxony, oat borders just 1 m wide reduced the number of winged aphids (especially *Rhopalosiphum padi* [bird cherry-oat aphid]) caught in potato fields and were more effective in reducing PVY spread than intensive use of insecticides.

Population monitoring/forecasts

Association of virus spread in potatoes with aphid flight activity is well documented. Aphid-trapping networks originally focused on *M. persicae* because it was considered the most efficient vector of potato viruses. As the importance of PVY spread by less efficient but abundant vectors was recognized, aphid-trapping networks began routinely identifying these aphids, e.g., since 1965, a network of 12.2-m suction traps has been deployed, first in the U.K, then in other European countries. The EXAMINE (EXploitation of Aphid Monitoring systems IN Europe) network, presently operates 73 traps in 19 countries.

Trapping networks are intended to monitor aphid flight on a regional basis. At any particular location, e.g., an individual farm, the first spring migrants may not be detected because their occurrence is rare and the sample unit small. Another limitation is that the traps may not be monitored daily and expertise is required to identify the captured aphids. A regional aphid trapping network, *Aphid Alert*, was operated in North Central U.S and southern Canada from 1992-94, and 1998-2003 (7).

Although the economic benefit of *Aphid Alert* to regional seed potato producers was estimated to be many times the cost of maintaining it, the program terminated when public funding ended and project personnel moved to other employment. For this reason, we explored using models based on meteorological data as a possible cost-effective surrogate for aphid trapping data (11).

Analysis of historic data sets showed that cumulative duration of early season low-level jet (LLJ) streams was strongly correlated with summer abundance of *M. persicae* and spread of both PLRV and PVY. Statistical models were developed relating frequency and duration of spring wind events to subsequent *M. persicae* abundance and severity of PLRV and PVY spread in the northern Great Plains. Results showed that the cumulative LLJ duration fit best with cumulative *M. persicae* capture through the first week of

August (R^2 ranging from 0.597 to 0.883), and the current season spread of PLRV fit best with inoculum and cumulative *M. persicae* capture through the first week of August ($R^2 = 0.75$, $P = 0.015$).

Action thresholds

Growers of fresh market or processing potatoes usually base their decision on whether to treat for insects on some assessment of pest densities, but the threshold concept may not be applicable to seed potatoes because of the biological complexities involved and the stringent phytosanitary standards that must be achieved. Static thresholds in the range of 20-100 aphids per 100 leaves have been proposed for ware production. Differences in susceptibility to virus infection among cultivars suggest that higher thresholds may be appropriate for some. Proposed action thresholds to minimize within-field spread of PLRV in cultivars susceptible to 'net necrosis' (a tuber defect associated with PLRV infection) and for use in seed potato production have ranged from 1-10.

Site-specific IPM

In 2003, we conducted on-farm research undertaken to determine whether seed potato growers could reduce use of methamidophos and still obtain a high level of *M. persicae* control (1). Experiments were conducted in 25 seed fields, each >8 ha, to evaluate effectiveness of targeted applications for aphid control. When a spike in aphid flight activity was observed, an 18 m wide spray swath of methamidophos was applied by airplane to border areas (i.e., at the ends of rows) abutting fallowed headlands. Pretreatment *M. persicae* densities were ~10 times higher in border areas than in field interiors. Methamidophos applications provided excellent control (>90%) of early colonizing aphids. Aphid densities mid-field, preapplication and 3 d after spray application, did not differ from densities in the sprayed borders 3 d after. In most fields, aphid densities increased at similar rates in the sprayed borders and untreated field interiors between 3 and 7 d after methamidophos application. Overall, 38.5 of 730 hectares were treated saving an estimated 92% compared to treating the entire field.

Host plant resistance

For many years, my laboratory has focused a major research effort on identifying sources of host plant resistance in wild potato species (3). This research has resulted in the development of advanced potato breeding lines that have high levels of resistance to *M. persicae* and *Macrosiphum euphorbiae* (potato aphid). Tuber yield and type in some of these selections is near agronomic acceptability.

It is often suggested that extant potato cultivars offer little promise as sources of useful aphid resistance. However, few prior studies have critically measured effects of host cultivar on aphid age-dependent life table statistics or related these measures to field performance. Therefore, we recently undertook comprehensive field and greenhouse study to assess 49 commercial potato cultivars, primarily of North American origin, for resistance to *M. persicae* and *M.euphorbiae* (2). Cultivars were found to show considerable differences in resistances to each aphid species, but these resistances were not associated ($R^2 = 0.032$). Aphid/predator population models using a *K*-value of 15.2 indicated that following colonization *M. persicae* populations would remain stable for 20 days on Russet Norkotah (resistant) whereas on Red La Soda (susceptible) populations would reach over 54,000. Population models indicated that with nonpersistent foliar insecticides as the only control, three applications would be necessarily to maintain *M. persicae* below the Minnesota recommended action threshold on Red La Soda for 21 days while just one application would be needed for 21 days control of *M. persicae* on Russet Norkotah.

It must be noted, that transgenic lines have been developed that are highly resistant, but not immune, to infection by PLRV, PVY, and PVX. While aphids can still acquire virus from low titre plants, efficiency of transmission is greatly reduced. Transgenic cultivars were released in the USA that expressed the *Leptinotarsa decemlineata* (Colorado potato beetle) specific toxin *Bacillus thuringiensis tenebrionis* (Bt) combined with PLRV replicase. Cultivars were also developed that expressed Bt and PVY coat proteins. This technology was far more effective than any presently used tactic, but these cultivars have been withdrawn because of concerns over a public backlash against genetically modified food.

Conclusions

Insecticides are valuable tools for preventing spread of PLRV, but seldom effective in limiting spread of non-persistently transmitted viruses. Cultural practices and reduced use of insecticides are often are among the most effective and inexpensive of control measures that growers can implement. Such practices are seldom complicated, but like all pest management tactics require application of knowledge of vector biology and ecology.

الملخص

راد كليف، إدوارد. 2006. استعمال البدائل الكيميائية لمبيدات الآفات المصنعة للمحافظة على صحة النباتات في محاصيل البطاطا/البطاطس المكاثرة بالطريقة الخضرية/ الكلونات. مجلة وقاية النبات العربية. 24: 170-173.

تعدّ الفيروسات المنقولة بحشرات المنّ السبب الرئيس لرفض لوطات بذور البطاطا/البطاطس أو خفض درجتها لإعادة التصديق. ويميل الزراع لاعتبار مبيدات الحشرات خط دفاعهم الأول ضد انتشار الموسم الحالي لفيروسات البطاطا/البطاطس في بذور البطاطا/البطاطس على أن استعمال هذه المبيدات لا يعطي الفائدة المرجوة في الحدّ من انتشار الفيروسات. وتستطيع مبيدات الحشرات منع انتشار فيروس التفاف أوراق البطاطا/البطاطس من مصادر ضمن الحقل نظراً لامتداد فترة سكون الاكتساب لهذا الفيروس المنتقل بالطريقة المثابرة. على أن حشرات المنّ المجنحة الحاملة للفيروس لا تقتل بالسرعة الكافية لمنع انتقال الفيروس المذكور حتى عند وجود بقايا المبيد القاتل للمنّ. وكافة فيروسات البطاطا/البطاطس الأخرى تنتقل أثناء بحث المن عن الغذاء خلال عدّة ثواني، الأمر الذي يجعل هذه المبيدات ذات أهمية ضعيفة. وتشمل البدائل غير الكيميائية لمكافحة الفيروسات سياسات لتخفيض التعرّض للإصابة مثل تحديد جيل إكثار البذور، التفتيش الحقلي الصيفي والاستئصال للحدّ من مصادر لقاح الفيروس ضمن الحقل، والاكثار خارج المواسم لتحت نماذج ممثلة من لوطات البذور وعدم تصديق تلك اللوطات التي يكون الفيروس فيها أعلى من الحد الحرج، والعزل الفراغي لإنتاج البذور بعيداً عن مصادر الفيروسات والضغط العالي للناقل، والاجتناب المؤقت للنواقل بما في ذلك القتل

المبكر للعروش الخضرية المصابة والتحكم بالبيئة لخفض أعداد الناقل. ويمكن استعمال تغطية الخطوط لحماية الأجيال المبكرة من إكثار البذور. وزراعة شريط من المحصول بعرض 3م حول حقول الإكثار، كما أن الوصول إلى نمو متجانس ضمن الحقل يقلل من استعمار المنّ للمحصول. ويمكن باستخدام الزيوت الزراعية الحدّ من انتقال الفيروسات غير المثابرة كفيروس البطاطا Y، في حين أن استخدامات مبيد آفات على أطراف الحقل عند بدء عمليات الغزو قد تقلص كثيراً من استخدام المبيدات وتكلفتها، مع المحافظة على الأعداء الطبيعية.

كلمات مفتاحية: منتجات خالية من الفيروسات، بذور البطاطا/البطاطس، تصديق، فيروسات منقولة بحشرات المنّ

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