CORKY RINGSPOT DISEASE:
Review of the Current Situation

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Introduction

Corky ringspot disease (CRS) of potato (*Solanum tuberosum* L) is caused by tobacco rattle virus (TRV) and vectored by stubby root nematodes (*Trichodorus spp.* and *Paratrichodorus spp.*) (Harrison and Robinson, 1986). The disease is characterized by arcs, concentric rings or diffuse extensive browning of tuber flesh that later dries into cork-like tissue, which make the crop unsalable. CRS was first reported in Washington in 1976 (Thomas, 1976) but seldom considered as a serious threat to crop production. However, in recent years CRS has emerged as a more serious quality problem of potato and occasionally caused crop failures in upper and lower Columbia Basin (Thomas *et al.*, 1992). Extensive survey of potato fields in Washington and Oregon shows that TRV and its vector, *Paratrichodorus allius*, are present in the most of potato growing regions, and the vector is more prevalent (30% of fields) than the virus (3% of fields). The severity of CRS symptoms varies considerably in problem fields. In some fields the symptoms consists of typical arcs and concentric rings, and in others the dark brown-black necrotic tissue engulfs the entire tuber, and tissue rot is caused by secondary organisms. The variable virulence of virus strains isolated from these fields has recently been confirmed (Mojtahedi, et al, unpublished).

The Virus:

TRV is a rod shaped virus with two genomic species, RNA-1 and RNA-2, packaged in long and short particles, respectively. While the long particle is responsible for infectivity, replication of virus and systemic spread in plants, the shorter particle contains genes for the coat protein and nematode transmission. Both particles have determinants for symptom expression. TRV isolates vary substantially in the sequence of RNA-2, and this variation gives rise to the large number of serological variants (Robinson and Harrison, 1989, and Brown *et al.,* 1995). Also, we have detected differences in the length of RNA-2 of TRV isolates in Washington and Oregon, which may be used to differentiate the more virulent strains (Crosslin *et al.*, unpublished). TRV is commonly transmitted to plants by stubby root nematode vectors (primary infection) or sometimes through true seed or clonal propagative materials like seed potato (secondary infection). Potato with secondary infection is occasionally systemically infected and may even produce blemished tubers, yet it does not always serve as virus source for nematodes to acquire and spread it. This may be due to presence of only RNA-1 in infected plants that self-eliminates TRV. In Scotland, potato with secondary infections exhibit stem mottle symptoms that have not been observed in Washington. Infected seed may also produce plants systemically infected with bipartite TRV. By examining a large number of potato plants grown from CRS blemished tubers of different cultivars and breeding lines, 20% were systemically infected with TRV (Crosslin *et al.*, 1999) yet only 5-6% served as virus source for *P. allius* to acquire and transmit it to an indicator plant (Samsun NN tobacco). Similar percentages of these test potato plants produced tubers with secondary infection (Mojtahedi *et al.*, unpublished). Crosslin *et al.*

(1999) found 12% of asymptomatic tubers from CRS problem fields produced plants with systemic infection. Similar results have been reported by Scottish researchers (Xenophontos *et al.*, 1998). Unblemished tubers with TRV infections would not be detected by seed certifying agents that have zero tolerance for CRS blemished tubers.

Crops commonly rotated with potato, like corn and wheat, were originally labeled as non-hosts for TRV (Brunt *et al.*, 1996). Early researchers employed a less sensitive technique (ELISA) to detect TRV in the roots of wheat and corn that contain relatively low virus titer. By using a more sensitive technique, reverse transcription polymerase chain reaction (RT-PCR) (Crosslin *et al.*, 1995), we have detected TRV in wheat (spring and winter) and corn (field, and sweet) roots and showed that *P. allius* can acquire and transmit it to an indicator plant (Mojtahedi *et al.*, unpublished). Additionally, wheat and corn are excellent hosts for *P. allius,* and nematodes will thrive on these crops and maintain the virus during 2-4 years rotation.

Alfalfa, another crop commonly rotated with potato in the Columbia Basin, is rarely infected with TRV, but is a suitable host for *P. allius*. In one study, a viruliferous population of *P. allius* became TRV free after feeding on Vernema alfalfa for 3 months (see The Vector below). Alfalfa and similar crops may be used as rotational crops to reduce TRV impact on potato (Thomas *et al*, 1999).

TRV is mostly restricted to the root system of its hosts (Harrison and Robinson, 1986), but like potato may occasionally go systemic and infect above ground parts including seeds. Some of the systemically infected hosts of TRV in the Columbia Basin include nightshades (black-*Solanum niger* and hairy -*S. sarachoides*), common chickweed (*Stellaria media*), and others (Lister and Murant, 1967, Cooper and Harrison, 1973, Davis and Allen, 1975, and Allen and Davis, 1982). It is noteworthy that nightshades and common chickweed are suitable hosts for *P. allius,* which can feed and may replenish its virus load.

The Vector:

P. allius is an obligate ectoparasitic nematode with a wide host range (Ayala *et al.,* 1970 and Mojtahedi and Santo, 1999). The nematode was originally described from an onion field in Lake Labish, Oregon (Jensen, 1963), and is the only stubby-root nematode we have detected in potato fields of Oregon, Washington, and some counties of Idaho. The base temperature for activity is 54 F, and at 68 F its life cycle lasts > 22 days (Ayala *et al.,* 1970).

P. allius is sensitive to moisture levels below field capacity (FC) (Mojtahedi and Santo, 1999), and may result in population decline. Soil moisture in potato fields are maintained at 85-90% FC for optimum tuber quality. Thus, *P. allius* population in a potato field will tend to be low (Mojthadi and Santo, 1999). Santo *et al.* (1997) have shown that CRS disease can be instigated by a low level of *P. allius* in the field. Their data showed that during the past 4 years *P. allius* levels in field plots ranged from 0-15 per 250 cm^3 after potato was planted, yet at harvest the tubers showed a 30-97% incidence of CRS. Under greenhouse conditions, three *P. allius* per 250 cm^3 soil was enough to cause CRS disease on Norkotah potato.

P. allius favors sandy soils and has been found at 3 ft deep in soil profile. This nematode can migrate only 1 ft upwards to transmit TRV to a host like potato (Mojtahedi and Santo, 1999). In contrast to *P. allius*, *P. minor*, the vector of CRS in Florida, migrated 6 ft upwards to enter the zone of fumigation after the fumigant was gone, rendering Telone II™ ineffective to control CRS (Weingartner *et al.*, 1983). Soil fumigation with Telone II™ has provided excellent control of CRS in Washington (Santo *et al.*, 1997), and Oregon (Ingham, *et al.,* 1995).

P. allius by itself is not known to cause any damage to potato. This may be due to low levels of *P. allius* present around potato during the growing season. In a greenhouse test, 130 *P. allius* per potato seedling did not cause measurable damages to Norkotah during 90 days of exposure (Mojtahedi *et al.*, unpublished)

The involvement of *P. allius* in transmission of TRV to potato was established in 1968 (Ayala and Allen, 1968), and was shown that nematode loses virus after each molt (*P. allius* molts four times). To remain viruliferous, *P. allius* has to reacquire TRV from an infected plant. Thus, on a crop like alfalfa which is a host for *P. allius* and none-host for TRV, *P. allius* will eventually become free from TRV after several generations (Mojtahedi *et al.*, unpublished).

The Disease:

Potato tubers newly formed on stolens are vulnerable to viral infection, and researchers in Florida (Weingartner *et al.*, 1975) showed that field grown tubers as small as 3-cm in diameter were blemished with CRS. In greenhouse experiment (Mojtahedi *et al.,* unpublished), Norkotah seedlings were grown for 3 weeks before inoculating with viruliferous *P. allius* immediately after transplanting or at 3 weeks intervals for 18 weeks. By delaying the inoculation for 9 weeks (plant age = 12 week), the tubers were asymptomatic compared to those inoculated at 0, 3, and 6 weeks after transplanting. *P. allius* were recovered from around all plants at harvest regardless of inoculation time. It appears that older tubers are less attractive for *P. allius* to probe and introduce TRV and/or they are resistant to viral infection.

The longer the tubers were exposed to *P. allius* in the field (Ingham, personal communication) or in greenhouse tests (Mojtahedi *et al.*, unpublished) the greater number of Norkotah and Russet Burbank tubers exhibited CRS symptoms. These observations suggest that the tubers which were infected at younger stages could remain asymptomatic (latent), before the CRS symptoms are expressed. Also, it indicates that early harvest of potato in problem fields to avoid a greater loss is beneficial only if the crop is processed immediately or sold to fresh market. Also, it indicate that controlling of disease should be directed towards protecting the young developing tubers (Weingartner *et al.,* 1975).

The Control Measures:

Nematicides: CRS has been successfully controlled by 15 and 20 gal/A of Telone II™ shanked at 16-18 in deep in field plots with high disease pressure (Santo *et al.*, 1997 and 1998). Telone II™ is registered at 25 gal/A for controlling CRS on potato. Temik™ applied 4 weeks after planting provided significantly greater protection against CRS compared to application at planting, probably due to higher potency at tuberization to protect vulnerable young tubers. However, at present, Temik™ is registered for use on potato only as an at plant treatment with the seed-piece with a 150 days pre-harvest restriction. Metham sodium products have failed to provide adequate control of CRS (Santo *et al.,* 1997 and 1998). Metham sodium in combination with a contact nematicide like Mocap™ has rendered mixed results. In Umatilla, OR (Ingham, personal communication), at high disease pressure site the combination treatment was not effective, whereas in low pressure site it effectively controlled CRS.

Crop Rotation: At present, no effective crop rotation has been recommended to control CRS on potato. Rowe (1993) suggested that alfalfa as none-host for TRV, may reduce the impact of CRS on potato. We have demonstrated that viruliferous *P. allius* would be free of TRV after feeding on alfalfa for 3 months. Therefore, an alfalfa field free from host weeds of TRV, may eliminate the virus from the nematode population. Investigation is underway to verify this.

Plant Resistance: The use of resistant potato cultivars is the most attractive and potentially the most effective method of controlling TRV, it is also desirable environmentally through the reduced use of nematicides. An extensive breeding program for controlling CRS in Washington is underway. Known European resistant cultivars and also breeding lines from Tri-State seed trials have been tested against the virus and vector populations, and crosses between prospective lines and commercial cultivars have been made (Crosslin *et al.,* 1999, and Brown *et al.*, 2000). Preliminary results indicate that the observed resistance in potato lines is not correlated to their host suitability for *P. allius*, but rather resistance is towards TRV (Brown *et al.*, 2000).

***Summary*:**

CRS is a quality problem of potato caused by TRV and vectored by the stubby root nematode, *P. allius*. The virus and vector are present in almost all potato growing regions of the Columbia Basin, with the vector being more prevalent (30%) than the virus (3%). Data suggest that seed potato can harbor TRV without expressing CRS symptoms. Infected seed can produce infected plants that serve as a virus source for nematode to acquire it. However, results indicate that planting infected seed will not lead to a crop failure. CRS can be effectively controlled by soil fumigation with Telone II™, which controls the nematode. Crop rotation with alfalfa and plant resistance are promising alternative control measures that are under investigation.

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