# Potato Progress

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With the 2021 potato season fast approaching, it is time to think about nematode control. Below is a re-release of a 2017 article by Russ Ingham (Volume 17, Number 7). At the time, supplies of Vydate C-LV were very low and it was not included in the discussion. Since then, supplies of Vydate C-LV from Corteva Agriscience have improved and the active ingredient (oxamyl) is also marketed by AMVAC as ReTurn XL. Therefore, a new article is included at the end of this issue that reviews use of oxamyl for management of Columbia root-knot nematode and corky ringspot. Comments on recent trials with Velum Prime and Movento are also included.

## 1. Re-release of Potato Progress Volume 17 Number 7.

# Nematode Management in the Face of Short Supply of Telone and Vydate

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Columbia root-knot nematode (CRKN, *Meloidogyne chitwoodi*) infects potato tubers and causes quality defects such as external bumps on the surface and small brown spots that can be as deep as ¼ inch under the surface. Most root-knot nematodes penetrate roots and cause the root to swell around the infection site producing a gall. The female nematode continues to grow, with her posterior close to the root surface. Once eggs are formed they are laid in an egg mass on the root surface surrounded by a jelly-like substance called a gelatinous matrix. When CRKN infect tubers, galls are formed under the skin causing the bumps seen on the surface. When females mature and lay their eggs in an egg mass in the tuber the gelatinous matrix is brown in color forming the noticeable brown spot about the size of a pinhead. Some discoloration also occurs as the tuber tissue reacts to presence of the foreign substance of the egg mass and walls it off. Another species, the Northern root-knot nematode (*M. hapla*) also infects tubers and causes small brown spots around the egg mass but does not cause bumps/galls on the tuber surface. Even light external or internal symptoms of root-knot nematodes make tubers unacceptable for domestic markets. This can lead to devaluation or rejection of the crop affected. Furthermore, in export markets where CRKN is considered a quarantined pest, a single female found in one tuber can result in the rejection of a shipment of potatoes from entry into that country. CRKN becomes active at 41 °F (5 °C) so it infects roots early in the season and produces a large number of offspring. Without treatment, densities of 1/250 g soil can result in crop rejection. Low tolerances for symptoms from infection plus low damage thresholds and rapid reproduction rates make damage a certainty if CRKN is not managed adequately.

Stubby-root nematodes (SRN, primarily *Paratrichodorus allius* in the Northwest) feed on root tips but cause little damage to potato. However, in some fields, SRN carries *Tobacco rattle virus* (TRV) which it vectors to potato plants by feeding on roots causing a disease called corky ringspot (CRS). Presence of TRV in tubers causes necrotic areas in the form of diffuse brown spots, that can be quite large, or arcs and rings. Symptoms can vary by variety. For example, symptoms in Russet Burbank tend to be diffuse spots while those in Yukon Gold are primarily arcs and rings. These necrotic spots, arcs, and rings are considered to be quality defects and tubers with even a small amount of symptoms are considered culls. Crops with as few as 6% culls can be downgraded or rejected. This can occur at densities of SRN as low as 3/250 g soil so SRN needs to be managed in any field with a history of CRS.

Over the last several years CRKN and SRN have been managed with the fumigants Telone and metam sodium and the nonfumigant nematicides Mocap and Vydate C-LV. However, there was an accident at the plant where Vydate was made and it is no longer available. Loss of Vydate has increased demand for Telone which was already in short supply due to a shortage in raw materials and demands from other markets. Managing nematodes in potato when these two key products are in short supply will likely require a combination of several strategies such as crop rotation, green manure crops, nematicide combinations, careful crop management to reduce symptom development, and combinations of these tactics.

***Management with Reduced Rates of Telone***

If a grower cannot obtain all the Telone that his farm requires his options are to use a full labeled rate on as many acres as he has sufficient product for or to treat more acres at a reduced rate and run the risk of inadequate control. The recommended rate for using Telone alone is 20 gpa. With reduced supply available, rates as low as 11 gpa are being proposed. Few studies have been done with rates lower the 20 gpa. In a trial completed in the Columbia Basin during 1994, 10 gpa of Telone reduced culls due to CRKN from 88% in the check to 14% which may not have been acceptable to processors (Ingham et al., 2000a). Telone at 15 and 20 gpa each reduced culls to 2%. In trials done in 1998 (Ingham et al., 2007a) and 1999 (Ingham and Hamm, 2000), Telone at 15 and 20 gpa reduced culls from 66 and 22 in non treated plots to 1% and 0%; (1998) and 5% and 5% (1999), respectively. However, in 1993, 15 gpa and 20 gpa of Telone only reduced culls from 57% to 8% and 23%, respectively, (Ingham et al 2000a), and in 2000 from 94% to 11% and 20%, respectively (Ingham et al., 2007a). Therefore, in some trials even the recommended rate had unacceptable levels of tuber damage.

In contrast, several trials in the Columbia Basin found that Telone alone was effective at controlling SRN and CRS at rates of 10 gpa or higher (Ingham et al., 2000b, 2007b). The discrepancy in the effectiveness of Telone alone between these two nematodes may be due to the fact that most CRKN are found in the top foot of soil whereas SRN are more evenly distributed with depth. This means that getting a good seal at the surface during Telone application is more critical for controlling CRKN to prevent survival. Therefore, when using reduced rates of Telone it is all the more critical to make certain conditions are optimal to maximize results. Shanks should be set 18 inches apart and set to inject at 18 inches deep. Soil moisture should be slightly below field capacity and temperature should be 50-60 °F. The soil should be worked up early to encourage the breakdown of roots and expose nematodes and their eggs and then worked into a good seed bed condition to provide a good seal after injection.

***Using Mocap or Metam Sodium with Telone***

Adequate control of CRKN with reduced rates of Telone may be achieved by using another product in combination with Telone. In a 1990 trial in the Klamath Basin, Telone at 15 gpa only reduced culls due to CRKN from 59% to 30% (Ingham and Rykbost, 1991) and in 1991 Telone at 20 gpa only reduced culls from 52% to 20% (Ingham, 1992). However, in both studies addition of a broadcast preplant incorporated (PPI) application of Mocap at 6 lb a.i./acre reduced culls to zero. While we have no data on combinations of

Mocap with rates of Telone less than 15 gpa, it is probable the there would be a benefit of Mocap to reduced rates of Telone as well, especially if the rate of Mocap was increased to 12 lb a.i./acre.

In the 1994 Columbia Basin study mentioned above in which Telone at 10 gpa reduced culls from 88% to 14%, addition of a water-run application of metam sodium at 38 gpa reduced culls to 1%. While these are the only data we have with metam sodium and Telone at 10 gpa we have several trials with combinations of Telone at 15 gpa and water-run or shanked-in metam sodium at 30 gpa and culls were reduced to 2% or less in all cases. Therefore, it is safe to assume that Telone at 11 gpa plus metam sodium at 38 gpa would be an effective treatment in most instances. It is speculated that the reason the addition of Mocap and metam sodium improve control of CRKN is that they help reduce nematode populations near the surface that may not be adequately controlled if there is not a sufficient seal during the Telone application. Since Mocap also persists in the soil for an extended period it may also help control nematodes migrating up from deeper depths. All these treatments would be effective for controlling CRS as well.

***Using Shanked-in Metam Sodium***

For fields in which there is not sufficient Telone available to treat in any fashion the choices are not to grow potatoes in those fields or to treat with some product other than Telone. While water-run metam sodium helps control nematodes when used in combination with Telone it is generally not effective as a stand-alone treatment. Over five trials, tubers culled from CRKN in non treated plots averaged 58% while those in plots treated with water-run metam sodium at 38 gpa averaged 30% (Ingham and Hamm, 2000, Ingham et al., 2000a, Ingham et al, 2007a, Rykbost et al., 1995). Tubers with CRS in six trials averaged 46% and 30% in non-treated and metam sodium treated plots, respectively (Ingham and Hamm, 2000, Ingham et al., 2000b, Ingham et al, 2007b, Rykbost et al., 1995). However, shanking metam sodium can be effective in suppressing nematode damage to tubers under low to moderate pressures. For example, in 1996 shanking in 30 or 38 gpa of metam sodium at 16 inches reduced culls due to CRKN from 47% in untreated plots to less than 1%. In a 2001 trial, metam sodium shanked-in at 6 and 12 inches (30 or 38 gpa) or at 6, 12, and 18 inches (50 gpa) reduced the percentage of culled tubers from 53% in non treated plots to 1% or less. This application procedure has not been adequate under high pressure situations where a higher percentage of tubers in untreated plots were culls (Ingham et al., 2007a). Tubers with CRS in 1996, 1999, and 2000 averaged 28%, 72%, and 24% in nontreated plots and 1%, 8%, and 3% in plots treated with shanked-in metam sodium at 38 gpa, respectively (Ingham et al., 2007b).

***Using Mocap with Shanked-in Metam Sodium***

Mocap can be used in combination with shanked-in metam sodium either as a broadcast PPI application or shanked-in with metam sodium as a tank mix. In a high CRKN pressure situation in 2000, check plots had 94% culls from CRKN (Ingham et al., 2007b). Metam sodium (38 gpa) shanked-in at 6 and 12 inches had 35% culls. Shanked-in metam sodium plus Mocap (PPI) at 12 lb a.i./acre had 15% culls while an injected metam sodium/Mocap tank mix at the same rates reduced percent culls to zero. Reducing the rates in this application method to 30 gpa of metam sodium and 9 lb a.i./acre of Mocap did not provide adequate control (12% culls). Metam sodium and Mocap tank mix applications would likely be effective for controlling CRS as well, provided that the disease pressure is not too high.

***Managing Nematode Populations before Treatment***

Without access to the highly effective fumigant nematicide, Telone, growers will need to be aware of the nematode population levels in their fields and reduce densities with cultural methods as much as possible. This may require sampling fields during the rotation in addition to the fall before planting potatoes. Discovering that a field has a high population level in the fall may not provide any option other than to not plant potatoes in that field the coming year. When high densities are present growers should use poor or non-host rotation crops and green manure crops to reduce populations. This will help the products that are available to be more effective. Management of CRKN populations for the next potato crop should begin as soon as the current crop is harvested. Densities of CRKN after potato should be low if they were managed successfully to prevent damage to the crop that was just harvested. However, some level of CRKN will still be present. Growing rotation crops that are hosts will increase population densities making future control more difficult, while growing crops that are poor or non hosts will decrease population densities making control more likely.

The host status of crops is determined by calculating the reproductive factor (Rf) which is equal to the final population density divided by the initial population density. For example, the population density at harvest divided by the population density at planting. Crops with an Rf value greater then l.0 are defined as good hosts (Rf greater than 10 = excellent hosts). Under good hosts populations will increase. Crops with Rf values from 0.1 and 1.0 are considered poor hosts. Populations are supported but at slowly declining levels. Crops with an Rf less than 0.1 are non-hosts where populations are not supported and densities decline rapidly.

Growing crops that are poor or non hosts can be effective at reducing populations of CRKN because it has no long-lived resistant stage. Second stage juveniles (J2) hatch from eggs and if they do not find a suitable host to infect they die. Unfortunately, most crops grown in rotation with potato tend to be hosts for CRKN although the Rfs can vary between different varieties. There is a high acreage demand for crops that are good hosts so growers need to grow both good hosts and poor or non-hosts in rotation in order to meet market demands and suppress CRKN. Cropping sequences should be designed to grow the best host crops early in the rotation reducing the subsequent population increase with poor or non-hosts later. Long-season host crops like field corn can increase CRKN to 10,000/250 g soil. If this increase happens late in the rotation it may not be possible to escape tuber damage if potatoes are the next thing to be planted. However, if this increase occurs early in the rotation it may be possible to reduce those populations again before potatoes are planted. For example, potatoes grown without nematicides after a cropping sequence of field corn-field corn-wheat had 68% less tuber damage than those grown after wheat-field corn-field corn (Ingham, unpublished data). In the latter case, high population densities were produced at the end of the rotation with no opportunity to reduce densities. In the former case wheat did not sustain the high population densities produced under field corn so numbers declined even though wheat is a host. In addition, because wheat is harvested earlier in the year there was time to plant a mustard blend green manure crop for the late summer and fall which suppressed population densities further. Whenever possible, short season crops with low Rf values such as sweet corn or peas followed by a non host green manure crop should be grown in the last year before potato. For example, a field corn crop grown in 2001 increased CRKN to nearly 11,000/250 g soil. However, by growing wheat followed by a radish green manure crop in 2002 and a green pea-lima bean-mustard green manure crop (Caliente 61) sequence in 2003, population levels were reduced to 3/250 g soil. When potato was grown without nematicides in these plots in 2004 only 2% culled tubers were observed at the end of the season. A conventional rotation of wheat–field corn-field corn had 100% culls (Ingham, unpublished data).

The best options for cover crops to suppress CRKN are the sudangrass hybrid cv Trudan 8 or the sorghum-sudangrass hybrid Sordan 79, radish cv Terra Nova, and the mustard blend Caliente 61. For the most part, green manure crops need to be chosen by variety as well as plant type as host status can vary by variety. In one study, a numbered line of hybrid sudangrass increased CRKN 9.5 fold over five months while Trudan 8 reduced population levels by 96% (Mojtahedi et al., 1993). However, while Trudan 8 and Sordan 79 are good for suppressing CRKN they are excellent hosts for SRN and should not be grown in a field with a history of CRS (Charlton et al., 2010). SRN and CRS are much more difficult to control with rotation since most plants, including weeds, are hosts to the nematode and the virus. Using green manure crops is one of the few options. Radish cvs Terra Nova and Doublet have been demonstrated to suppress CRKN, SRN and CRS (Charlton et al., 2010, O'Neill, 2016).

***Minimizing CRKN Damage in a Current Potato Crop.***

Several cultural procedures can be used to minimize tuber damage in a potato crop that has not received adequate treatment. Plant the shortest season cultivar as possible. The longer a crop remains in the field the more degree-days will accumulate resulting in more CRKN generations, greater population increase, tuber infection, and symptom expression. Harvest as soon as possible and do not leave tubers in the ground longer than necessary. Once vines are killed, soil and tuber temperatures rise, increasing the rate of development for nematodes that have infected tubers and resulting in more extensive symptom expression. This has been substantiated in a number of studies. In one case the percentage of tubers culled from CRKN increased from 18% to 72% when harvest was delayed by three weeks (David and Ingham, unpublished data). Since CRKN in tubers continues to develop at temperatures above 41 °F, store tubers as cool as possible and have the crop processed as soon as possible.

***Summary***

In summary, to successfully manage nematodes when key products are in short supply growers should:
1) Use a reduced rate of Telone with full rate of metam sodium or Mocap
2) Make sure conditions are optimal for Telone
 considering shank spacing, temperature, moisture, seal
3) Shank in metam sodium at full rate
 with Mocap broadcast ppi or, preferably, as a tank mix
4) Manage nematodes with rotation crops and green manure crops
5) Manage potato crop to minimize damage should infection occur
 This is more relevant for root-knot than for corky ringspot.
 Once tubers are infected with TRV there is little that can be done.
6) Sample so they know what they have

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## 2. New article from Russ Ingham

# Nematode Management with Oxamyl and Velum Prime

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Over the years we have developed standard programs for nematode management with oxamyl (Vydate C-LV manufactured by Corteva Agriscience, ReTurn XL manufactured by AMVAC) in potato. Oxamyl can significantly suppress damage to tubers from Columbia root-knot nematodes (CRKN, *Meloidogyne chitwoodi*) and corky ringspot (CRS) which is caused by tobacco rattle virus (TRV) that is vectored by stubby-root nematodes (SRN, *Paratrichodorus* spp. and *Trichodorus* spp.) but it has a short half-life and so timing of applications is critical. Persistence of oxamyl is also sensitive to pH so it should be buffered to pH<5 before application. The best performance will be attained when an oxamyl program follows a shanked-in fumigant.

***Early Applications Are Essential***

CRKN over-winter in the soil as first-generation second stage juveniles (J2) or as eggs that hatch to J2 in the spring. Because CRKN has a low basal temperature for development (41 F) it is capable of infecting potato roots as soon as they are formed where they develop to adult females that lay second-generation eggs. Each female is capable of laying several hundred eggs. It is the J2 from second and later generation eggs that infect potato tubers and cause symptoms. Because of the multiplying factor from multiple generations, it is critical to reduce first generation J2 as much as possible with preplant fumigation and/or Mocap (see Potato Progress XVII Number 7 above). Another effective approach is with an in-furrow application of oxamyl (2.1 to 4.2 pts/A) at planting. For example, the average percentage of culled tubers (6 or more infection sites/tuber) from four trials between 2002 and 2004 was 34% without an in-furrow application and 3% with an in-furrow application.

Similarly, the percentage of tubers devalued due to CRS in 2004 was reduced from 9% (treated 41, 55, 69 and 83 days after planting, DAP) and 18% (treated 55, 69 and 83 DAP) to 0% and 6%, respectively, with an in-furrow application (Charlton et al. 2010).

***Post Emergence Applications***

Another application we have studied extensively is a chemigation of 2.1 pts /A (1 lb a.i./A) at emergence. Invariably this treatment has made little difference in the amount of tuber damage caused by CRKN. At this point in the nematode's population cycle the majority of first-generation J2 have invaded roots or died in the soil and there are few that would be susceptible to contact with the nematicide.

In contrast, a post-emergence application (treated 41, 55, 69, and 83 DAP) did reduce CRS (9%) compared to the same treatment program without the post emergence application (18%). Since SRN are ectoparasites they would be present in the soil and susceptible to contact with the nematicide at any time. However, even by 41 DAP the SRN had transmitted the virus that resulted in tuber damage at harvest. Therefore, if a crop is not treated early, it cannot be rescued from CRS with applications later in the season.

***Mid-season Applications***

Second-generation CRKN that hatch from eggs laid by first-generation females migrate through the soil and infect roots to produce third-generation J2 or infect tubers where they cause quality defects. During this period, second and later generation J2 are susceptible to contact with oxamyl and applications beginning at this point are effective at reducing tuber damage. Pinkerton et al. (1991) determined that second generation eggs hatched at 950 degree-days base 5 C (= 1,700 degree-days base 41 F ($DD_{41F}$)). It is recommended that chemigation applications of oxamyl should begin at 1,440 $DD_{41F}$ to have the nematicide present in the soil before the eggs hatch. This also helps to protect tubers from infection by J2 that hatch before 1,700 $DD_{41F}$. While this may only be a small portion of the total population it may still result in visible tuber damage by harvest. Soil temperature should be measured at tuber depth (about 8 inches). Because soils accumulate degree-days faster as they warm in the spring, crops planted later will take less time to reach 1,440 $DD_{41}$. During 2019, 1,440 $DD_{41F}$ was estimated to have been reached at 92, 81, 69, 62, and 60 DAP for potato crops planted in the southern Columbia Basin on March 1, March 15, April 1, April 15, and May 1, respectively. Since second and later generation J2 will continue to hatch for the rest of the growing season and because oxamyl has a short half-life, applications must continue at 14-day intervals for the rest of the season. Since potato crops are only allowed 9 lb a.i./A, growers should determine if they will have enough allowable a.i. to carry them until the end of the season based on their anticipated harvest date. If they do, they can consider adding an application at emergence. If not, that application is probably more efficacious at the end of the season than at emergence.

***In-furrow Vydate vs In-furrow Velum Prime***

Both in-furrow and in-season applications of oxamyl are required for suppression of tuber damage from CRKN. However, many growers are reluctant to use oxamyl in-furrow because of the potential for worker exposure and the toxicity of the compound (has a Danger label). Recently we have tested Velum Prime (fluopyram, Bayer CropScience) as a potential, less toxic (has a Caution label) replacement for oxamyl in-furrow. In a 2016 trial, in-furrow applications of Vydate (4.2 pts/A), Velum Prime (6.5 oz/A) or Vydate plus Velum Prime followed by three in-season applications of Vydate (2.1 pts/A) were equal at significantly reducing CRKN culled tubers (11%) compared to an untreated control (49%). Untreated plots during a 2017 trial had 65% culled tubers while in-furrow Vydate plus four in-season applications reduced culled tubers to 10% and Velum Prime in-furrow plus in-season Vydate reduced culls to 2%. In a 2018 trial with high nematode pressure, control plots had 95% culls while in-furrow Vydate or Velum Prime followed by a full in-season program of Vydate reduced culls to 27% and 18%, respectively. Another trial in 2018 demonstrated the importance of following in-furrow Velum Prime (45% culls with Velum Prime alone) with a full in-season program of Vydate (3% culls with Velum Prime plus Vydate). From these trials it would appear that growers concerned about using Vydate in-furrow should consider using Velum Prime. In addition to being less toxic it was marginally better than oxamyl in 3 of 4 trials. Replacing a 2 lb a.i./A of oxamyl in-furrow would allow two additional 1 lb a.i./A in-season applications. This could be important for long-season crops where the grower may run out of allowable a.i. (9 lb/A) before the end of the season. As with oxamyl, replacing in-furrow Velum Prime with two post emergence applications was not acceptable. Similarly replacing two early midseason chemigation applications of Vydate with foliar applications of Movento (spirotetramat at 2.51 oz/A) reduced control. Therefore, if Movento is used it should be used in addition to oxamyl and not as a replacement for it.

Unfortunately, we have no trial data on the effect of Velum Prime on CRS.

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