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INTERNAL DRY SCALE AND ASSOCIATED BULB ROTS OF ONION

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Internal Dry Scale and Associated Bulb Rots of Onion

As onion growers and packers in the Pacific Northwest (PNW) examined bulbs going into storage or being pulled out of storage in the 2014–2015 season and the 2015–2016 season, a common problem was observed on red, white, and yellow cultivars—internal dry scale. In bulbs with dry scale, the top quarter-inch to one-inch of one or more internal, fleshy scales had collapsed partially or fully into a paper-thin layer (Figure 1). The incidence of bulbs affected has ranged from less than 1% to greater than 30%. In some bulbs, symptomatic scales were dry and papery. In others, fungi, bacteria, and/or yeasts colonized the internal dead scales, leading to a rot of the fleshy scales.

Bulbs with internal dry scale symptoms harvested from drip- or furrow-irrigated crops in Washington, Oregon, and Idaho often are colonized by the fungus *Fusarium*, particularly *F. proliferatum*. *Fusarium proliferatum* is a different species from the causal agent of Fusarium basal rot of onion, *F. oxysporum* f. sp. *cepae* (du Toit et al. 2003; Schwartz and Mohan 1995). Bulbs with internal dry scales that are infected with *F. proliferatum* display white to light pink fungal mycelium on the dead, internal scales and in the cavity around the dry scales (Figure 2). These fungi can cause a dry rot in the fleshy end of the colonized scales, which remain dry and rubbery.

Figure 1. Symptoms of internal dry scale in onion bulbs of diverse cultivars grown in the semiarid PNW in 2014 and 2015.

Figure 2. Colonization of internal dry scales of onion bulbs by the fungus *Fusarium proliferatum* (upper left photo: note white fungal growth on the thin, dry scales, with a dry rot extending into the fleshy end of the scales); various bacteria (upper right and lower left photos: note a wet rot extending into the fleshy scales towards the basal plate to varying degrees); and yeasts (lower right photo: note a moist rot extending down the length of the fleshy scales and between adjacent scales).

In bulbs harvested from overhead-irrigated crops, or fields irrigated later than optimal for field curing, the collapsed, internal scales often are colonized by bacteria such as *Burkholderia*, *Pantoea*, *Enterobacter*, and other genera. Occasionally, the internal dry scales are colonized by yeasts such as *Kluyveromyces*. Secondary bacterial colonization of the dry scales can lead to a wet rot of the fleshy end of the scales (Figure 2; Schwartz and Mohan 1995).

In the 2014 and 2015 onion seasons in the PNW, bacterial rots typically were restricted to scales with internal dieback, and extended partially or all the way to the basal plate. However, in the few bulbs in which internal dry scales were colonized by yeasts, a moist rot progressed rapidly between adjacent fleshy scales (Figure 2). The common feature of bulbs with these rots was premature dieback of emerging leaves during bulb formation, resulting in internal dry scale.

The type of irrigation and other field practices may have determined whether the dead internal ends of scales were colonized secondarily by fungi, bacteria, or yeasts.

Microorganisms capable of colonizing these dead scales are common in soils and can be deposited into the necks of onions during the latter part of the growing season by splashing water (irrigation or rain) or windblown soil (e.g., *Fusarium* spores readily become airborne during cultivation, undercutting, harvest, etc.). If the dry internal scales stay moist as a result of irrigation, particularly irrigation later than ideal for field curing, the dry neck and upper bulb tissues combined with excess moisture enable fungi, bacteria, and yeasts to grow on the dry internal scales (Schwartz and Mohan 1995).

For information on primary onion bulb rots associated with fungi, bacteria, and/or yeasts, regardless of the absence or presence of internal dry scale, refer to the onion bulb rot section by Ocamb and Gent in the *Pacific Northwest Plant Disease Management Handbook*.

Internal dry scale is observed sporadically on onion in the PNW. A common cause is severe iris yellow spot caused by *Iris yellow spot virus* (IYSV), which is vectored by the onion thrips, *Thrips tabaci* (du Toit et al. 2004; du Toit and Pelter 2005; Gent et al. 2006). Severe IYSV infection can cause premature dieback of leaves in the onion bulb neck, even preventing the tops from falling over when the bulbs mature (Figure 3).

Drip- and furrow-irrigated crops tend to be affected more severely by thrips and IYSV than center-pivot-irrigated crops. Dry internal scales associated with severe IYSV infections usually are not colonized by bacteria or yeasts, but by fungi like *Fusarium* since the fungal spores are readily dispersed when soil is disturbed by field practices.

Why is internal dry scale so prevalent in seasons like those of 2014 and 2015?

Iris yellow spot was observed in the PNW in 2014 and 2015, but many crops that produced bulbs with internal dry scale did not have severe iris yellow spot. However, 2014 and 2015 were the hottest growing seasons on record or in the past 60 years for areas of the Inland PNW (Figure 4).

The Columbia Basin of Washington State experienced one of the warmest summers on record in 2014, and 2015 was even hotter. The Washington State University AgWeatherNet station in Pasco, Washington, recorded the longest period with

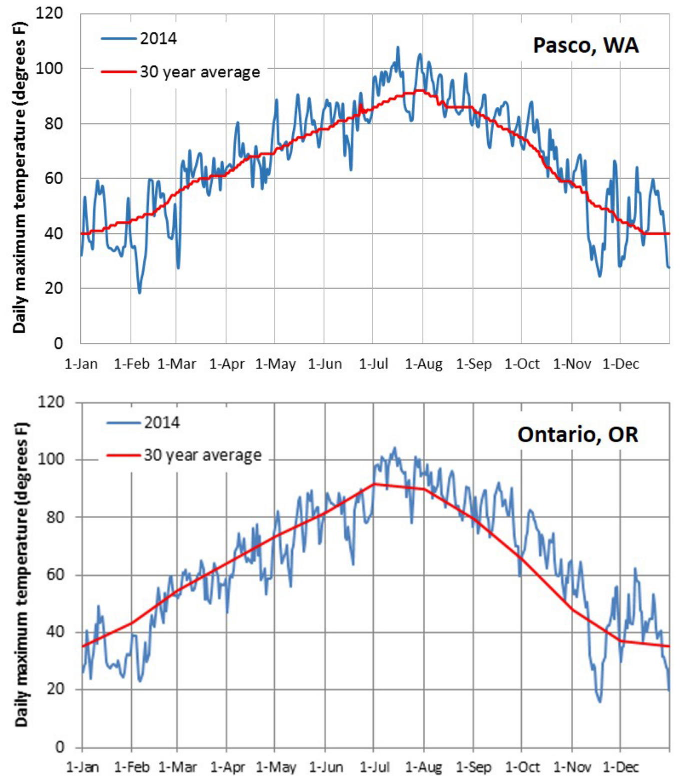

Figure 4. Daily maximum air temperature (blue line) in 2014 compared to the 30-year average daily maximum temperature (red line) recorded at weather stations in Pasco, Washington (top graph) and Ontario, Oregon (bottom graph). (Graphics by Tim Waters, Washington State University; and Stuart Reitz, Oregon State University.)

maximum air temperatures greater than 90°F in 2014 (July 1 to July 19), and the two longest periods with maximum air temperatures above 100°F in 2014 (July 12 to July 14 and July 28 to July 30). Nearly all months during the 2014 season exceeded 30-year averages, but July and August, a critical period for bulb growth, were particularly warm (Figure 4). In the summer of 2015, there were 22 days in which temperatures exceeded 100°F, and the hottest temperature recorded in 2015 was 113°F in June.

Figure 3. Severe leaf dieback caused by IYSV in a drip-irrigated onion bulb crop in 2007 (left), and extensive internal dry scale prevalent in bulbs harvested from this field as a result of premature leaf dieback (right).

In 2014, the Treasure Valley of eastern Oregon and southwestern Idaho also experienced a summer and fall that were the warmest on record (Figure 4). The Agrimet weather station in Ontario, Oregon, recorded 45 days with temperatures exceeding 90°F, with 27 days in July 2014 when the high temperature exceeded the historical monthly mean for daily high temperatures. The mean daily maximum temperature for July 2014 was 97.3°F, 6.3°F above the historical mean daily maximum of 91.0°F, and the mean low temperature was 6.1°F above the historical mean low. Also, temperatures remained warm into harvest. September 2014 had 20 days with high temperatures above the historical monthly mean for daily high temperatures, and the first frost did not occur until late October, more than 2 weeks later than the 30-year average date. Night temperatures also were above average, with minimum temperatures above the historical monthly low average temperature for 23 to 26 days each month from July through October 2014. As for the Columbia Basin, 2015 was even hotter than 2014 in the Treasure Valley.

Heat stress-induced physiological shutdown of onions

When onion plants are exposed to temperatures greater than about 85°F to 90°F, the plants reduce their physiological activity dramatically. They take up less water and the rate of growth of new leaves slows rapidly. Emerging leaves may die. The level of heat stress in the PNW in 2014 and 2015 is thought to be the primary cause of widespread internal dry scale.

Heat stress-induced physiological slowdown of onions was documented as early as the 1970s by J. L. Brewster, who is the author of *Onions and Other Vegetable Alliums*, 2nd Edition (Figure 5). Spanish-type storage onions grown in the PNW are more heat tolerant than cultivars grown in the 1970s, and growers now have sophisticated methods of field curing, postharvest curing, and storage to minimize storage rots associated with such stresses. However, all cultivars go into a state of physiological slowdown under sufficient heat stress, and the extended heat stress in 2014 and 2015 occurred during critical periods of bulb sizing in June to August.

The location of scales within bulbs that develop internal dry scale gives an indication of the age of the leaves affected. For most symptomatic bulbs from 2014 and 2015, internal dry scales were associated with leaves that would have emerged during hot periods in June to August.

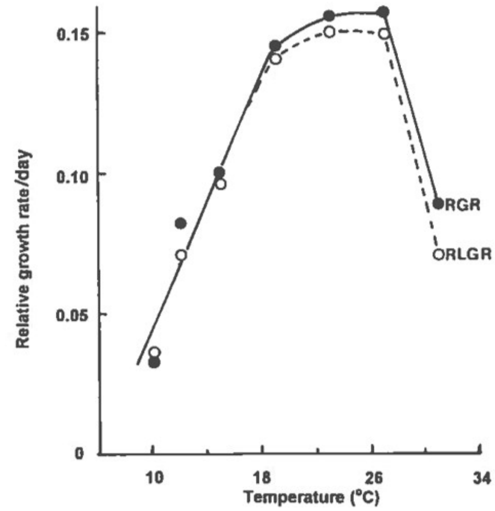

Figure 5. The effect of temperature on relative growth rate (RGR) of plant dry weight (black circles) and relative leaf growth rate (RLGR) of the onion cultivar Hygro (white circles). A temperature range of 10°C to 34°C corresponds to 50°F to 93°F. (Reprinted with permission from Brewster, J.L. 2008. Onions and Other Vegetable Alliums, 2nd Edition, which cites this figure from the original publication by Brewster, J.L. in 1979.)

Although onion crops need significantly less water during excessive heat because of physiological slowdown, some growers may not reduce irrigation adequately during these hot periods. This may reflect a lack of awareness of onion crop moisture use during such hot conditions. It may also reflect concerns with irrigation management during years of pending water restrictions (e.g., in regions of the Treasure Valley, where growers may have a “use it or lose it” scenario).

Excessive irrigation increases the risk of colonization of dying internal scales by fungi and bacteria common in soils in this region. The extent of excessive irrigation of onion crops in the PNW during 2014 and 2015 was also expressed by widespread problems with Fusarium basal rot (caused by *Fusarium oxysporum* f. sp. *cepae*) and basal plate splitting. Fusarium basal rot is exacerbated by excessive irrigation (Ocamb and Gent 2015b; Schwartz and Mohan 1995). Basal plate splitting is caused by wide fluctuations in soil moisture and is exacerbated by excess nitrogen (Conn 2012).

In 2014 and 2015, some Treasure Valley growers noted that their onion crops had not reached adequate size close to harvest time, probably as a result of heat stress-induced physiological slowdown during June to August. Many growers irrigated 7 to 10 days later than is typical in an attempt to increase bulb size, which dramatically increased the risk of fungal and bacterial bulb rots during storage.

How can growers limit internal dry scale and associated bulb rots during periods of heat stress?

There is much we do not understand about heat stress and physiological slowdown in onions. The phenomenon has been studied extensively in crops like potato since heat stress can significantly reduce potato tuber quality (Figure 6). The primary effect on potatoes is that plants slow down or stop growth during heat stress, and resume growth after the stress is relieved. The successive growth results in mobilization of starch from tubers to the plant tops, which decreases tuber specific gravity and, therefore, tuber quality. This may also result in knobby tubers, although knobby tubers may be associated with irregular irrigation.

Potato plants drastically reduce uptake of moisture during heat stress, yet the consequences of over-irrigation only become evident at harvest. As a result, potato growers are becoming diligent about monitoring crop moisture demand using real-time soil moisture sensors. These sensors are used to avoid excessive irrigation during hot periods, particularly when tubers are bulking.

Understanding the relationship between heat stress and physiological slowdown in onions will help growers adjust their irrigation practices accordingly to reduce the risk of adverse effects associated with overwatering. Research is needed to understand how onion cultivars in the PNW are affected by heat stress, particularly if the prediction of climate change becomes a reality, and more frequent and intense heat stress periods occur in the future. The 2012 growing season was hotter in the PNW than the historical average, 2013 was hotter than 2012, 2014 was hotter than 2013, and 2015 was hotter than 2014 (see *My Pest Page* for historical weather data across the PNW).

Real-time soil moisture sensors should be used to monitor crop moisture demand accurately, and to adjust irrigation during heat stress, particularly in the latter part of the growing season. An increasing number of onion growers in the PNW are using real-time soil moisture sensors, but many have stated they are still learning how to interpret and trust the output from sensors so they can modify their irrigation practices accordingly. The Oregon State University publication *Successful Onion Irrigation Scheduling* is a useful extension guide on irrigation scheduling for onion crops.

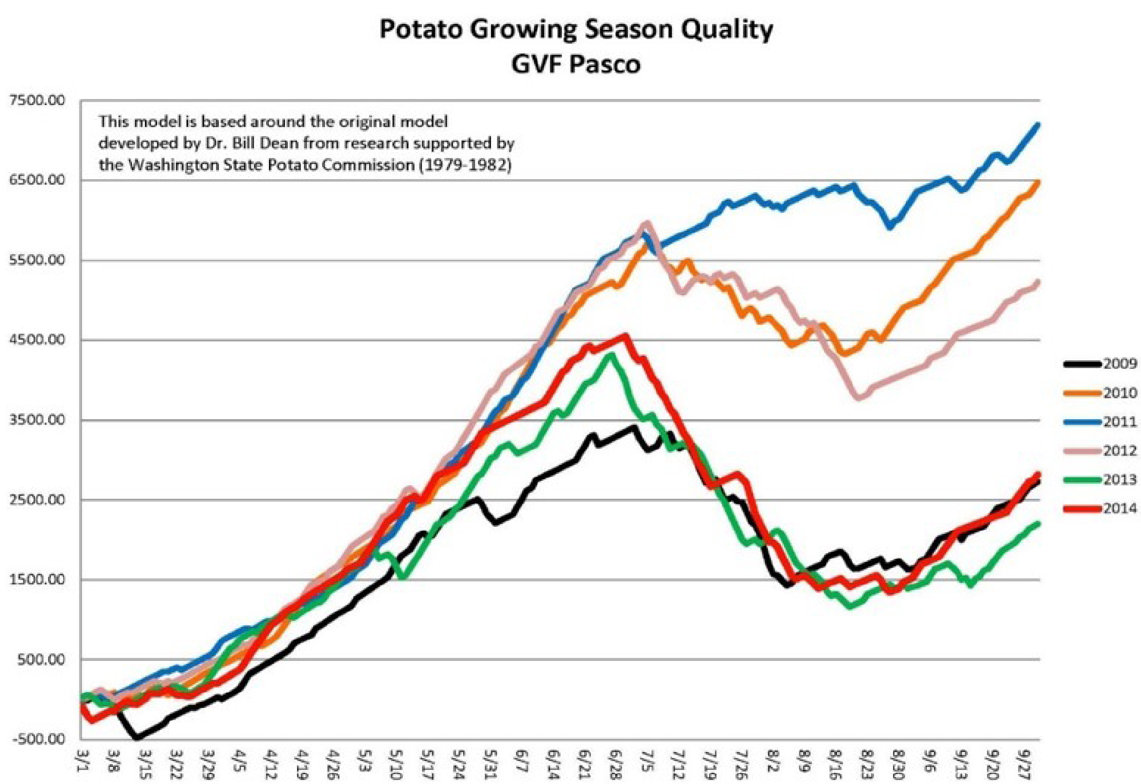

Figure 6. The quality of the annual potato growing season for the Pasco region of the Columbia Basin in Washington State from 2009 to 2014, based on the effect of temperature on potato tuber quality. Potato tuber quality declines as a result of heat stress (e.g., from early July to mid-August in 2009, 2013, and 2014) and does not completely recover after the stress is alleviated. (Reproduced with permission from Dr. Bill Dean, River Point Farms, Irrigon, Oregon).

Growers are encouraged to scout onion fields during and after heat stress periods to check for symptoms that indicate dieback of emerging leaves or other evidence of internal dry scale. Growers are also encouraged to invite university crop extension personnel, field representatives, or consultants to inspect their crops if suspect symptoms are observed. This will help improve our understanding of the risks and early symptoms of internal dry scale.

Careful monitoring of crop moisture demand to increase our understanding of onion physiology, particularly close to harvest, will help in the development of effective management practices to reduce the impact of internal dry scale on this important region of onion production. If secondary fungal or bacterial colonization of the collapsed internal scales has occurred or is suspected, recommended late-season management practices for fungal and bacterial bulb rots should be followed closely. This includes appropriate irrigation practices detailed above, timely late-season application of relevant fungicides for management of Botrytis neck rot (caused by *Botrytis aclada* and *B. allii*) and black mold (caused by *Aspergillus niger*), late-season copper and/or disinfectant applications to limit bacterial development, and relevant field curing and postharvest curing practices such as undercutting, swathing, and the use of forced air for rapid drying of the onion bulb tops and necks. Refer to the Ocamb and Gent publication *Onion* (Allium cepa)*–Bulb Rots* for detailed information on management of onion bulb rots.

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