Impact of drainage problems on cranberry yields: Two case studies

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Abstract.

The impact of two drainage problems on cranberry yield was investigated. In the first case, a yield decline of 39% was measured for cranberries growing over clogged drains and, in the second case, an inadequate design of the drainage outlet was associated with a 25% yield reduction. This yield decrease vanished the following year after redesigning the outlet.

Résumé.

L’impact de deux problèmes de drainage sur le rendement de la canneberge a été investigué. Dans le premier cas, le rendement a diminué de 39% dû au colmatage des drains tandis que dans le deuxième cas, une mauvaise conception de l’exutoire de drains a résulté en une baisse de rendement de 25%. Les correctifs apportés ont fait disparaître cette baisse l’année suivante.

Key words. Drainage - Clogged drain pipes - Iron ochre - Cranberry

Ten-cm diameter corrugated plastic drain pipes are often used for controlling the water table depth in cranberry production. Because recent work identified cranberry as sensitive to hypoxic conditions, the drainage system must be fully effective. Pelletier et al. (2016) observed that when the soil was saturated early in the growing season, photosynthesis declined after only one day of waterlogging. Also, Laurent (2015) showed that prolonged periods of hypoxic conditions (soil water potential (SWP) > -3.0 kPa) lead to a decline of plant productivity.

Drainage problems are an important factor limiting cranberry yield (Baumann et al., 2005). Poor design of the drainage system related to inappropriate drain depth or spacing and clogged drain pipes are two of the main problems encountered in agricultural production. Mineral sedimentation (Gallichand and Lagacé, 1987) or sludge deposition associated with bacterial activity in drain pipes (Ford, 1979) considerably reduce water entry into drain pipes. Sludge depositions generally contain organic matter (2 to 50% dry wt.) and form red to tan filamentous masses when combined to iron ochre, black gelatinous deposits when combined to manganese, and white to yellow stringy masses when combined to sulfur (Ford, 1993). In this paper, two case studies were investigated for characterizing the yield losses associated with drainage problems in cranberry production in Québec region.

CASE STUDY #1

In the first case, a grower reported, by the end of May 2011, that organic cranberries in half a bed cropped with the Stevens variety were yet dormant (red vines) lagging behind the other half bed, where cranberries were active (green vines). In this bed (525 m long and 54 m wide), there was a drainage outlet (90 cm depth) at each end and the highest point of the four drain pipes (60 cm depth) was located in the middle of the bed; the subsurface drainage system was therefore cone-shaped. By digging a soil profile, it was readily observed that the sandy soil was saturated under the red vines section, but not under the green vines section, and drain pipes were suspected to be clogged in that section. On June 7, chimneys were connected to drain pipes in the middle of the bed and a cleaning system used for removing the clogging material. The cleaning system consisted of a 2.5-cm diameter flexible hose inserted into the chimney, connected to a 3.75 kW gasoline pump operated at 300 kPa and delivering 35 m^3 h^{-1} of water. The water leaving the drain outlet was black and contained clumps of clogging material. These swollen masses smelt bad, were gelatinous and some masses were white to yellow with tan tinges while some were red to tan with black tinges (Fig. 1). After cleaning, red to tan deposits were found in some of the drain perforations, but not at the outer surface of the synthetic drain envelope. The red vines slowly turned to green three weeks after cleaning, but some died (Fig. 2). Before cleaning the drains, the soil solution was sampled (n=3) for Mn and Fe^{2+} analysed with the color disk method (model MN-5 and IR-20; Hach Company; Loveland, Colorado). The clogging material was also sampled (n=3) for measuring the organic matter content after burning in a muffle furnace at 550°C. At the end of the growing season, yield samples (n=25; 929 cm^2/sample) equally distributed in each of the two sections of the bed were collected. The yield difference between the two sections was analysed using the GLM function of R (R Foundation for Statistical Computing, Vienna, Austria).

Cranberries growing over the clogged drain pipes yielded a significant yield loss of 39% ($p < 0.001$) relative to cranberries growing over properly functioning drain pipes. Indeed, the yield was 21951 kg ha^{-1} in the poorly drained section and 36135 kg ha^{-1} in the well drained section. Although it was not measured, the yield reduction in the poorly drained section most likely persisted in the subsequent years, because of plant death.

Analyses of the soil solution did not detect Mn, but resulted in Fe^{2+} concentration of more than 5.0 ppm, i.e. the maximum value detectable by the color disk. According to Ford (1982), Fe^{2+} levels above 2.5 ppm are problematic for drainage systems and often present severe ochre problems. A concentration of 24% of organic matter (dry wt.) was found in the swollen masses, much higher than the ~1% typically found in sandy beds. Similar concentrations (~20%) were found in ochre deposits in Scotland (Wheatley, 1988). Although the sulfur concentration was not measured, the color, the smell, the presence of organic matter and iron, all pointed to the swollen masses being composed of iron ochre mixed with sulfur slime (Ford, 1993).

As Fe^{2+} can complex with many organic compounds (Wheatley, 1988), the organic fertilizers added to the soil surface may have migrated inside the drain pipes, then becoming potential sources of energy for ochre formation. The Fe^{2+} in solution in the drainage water is further oxidized by the action of heterotrophic bacteria using the soluble Fe-organic matter complex as an energy source or by filamentous bacteria (Wheatley, 1988). These reactions result in the formation of gelatinous iron ochre deposition adhering to the drain pipe walls and consisting of bacterial filaments that have adsorbed colloidal Fe^{3+}, silt, quartz, ions such as silica, and other amorphous material (Wheatley, 1988).

CASE STUDY #2

In the second case study, a drainage problem was suspected in half of a bed (454 m long and 45 m wide) cropped in conventional production and planted with the Stevens variety in 2003. By investigating the temporal variation of tensiometers values (model HXM80; Hortau, Lévis, Québec, Canada) after two rainfall events during blooming, we observed that SWP remained above the problematic threshold (> -3.0 kPa; Caron et al., 2016) for 18 h longer (52 vs 34) in one half of the bed (Fig. 3a). By inspecting the drainage system, it was found that the corresponding drainage outlet was ~50 cm closer to the ground than the drain pipes (90 cm depth), thereby decreasing the hydraulic head and slowing down drainage. This problem was corrected by moving the drainage outlet below the drain depth. The drainage time was then similar between both parts of the bed (Fig. 3b). The yield was estimated by harvesting samples (n=204; 929 cm^2/sample) in each of the two sections in 2011; this sampling was repeated in 2012 for evaluating the impact of the correction. The yield difference between the two sections was analysed using the GLM (generalized linear problem) function of R (R Foundation for Statistical Computing, Vienna, Austria).

In 2011, a significant yield reduction of 25% ($p < 0.001$) was measured in the section with slower drainage (32884 kg ha^{-1}) compared to the faster drainage section (43624 kg ha^{-1}). After correcting the problem, the yield difference between both parts of the bed became non-significant the next year ($p = 0.12$; 44003 kg ha^{-1} vs 47167 kg ha^{-1}).

PRACTICAL IMPLICATIONS

Even though the two drainage problems presented in this paper led to yield losses of 25 and 39%, they were diagnosed in good yielding beds. In the case of low yielding beds, the drainage efficiency should be investigated to verify if drainage problems could be an explanation of the low yields.

Some actions could be taken for limiting the detrimental effect of clogged drains on cranberry yield. The use of tensiometers could have prevented the problem early in the growing season by monitoring SWP. Including access chimneys to the drain pipe network is inexpensive and may be very useful when clogging problems are suspected. A pushrod inspection camera can be used to look inside the drain and evaluate the clogging problem. Because cranberries are cultivated over sandy soils and that iron ochre is more susceptible to deposit in drain pipes installed in sandy soils (Gameda et al., 1983; Ford, 1982), the problem of clogging drains by organic slime is of primary importance in cultivation of cranberries, particularly in the organic production where organic fertilizers are used. Washing drain pipes with injection of water can temporarily correct the problem but further investigation will likely be required to permanently solve this problem. The voids in the soil are also likely clogged by the organic slime, which could considerably reduce the soil hydraulic conductivity and warrant further investigation.

Using tensiometers allowed diagnosing the drainage problem related to the drainage outlet and applying an adequate correction. Because the original design of the drainage system dated from 2003, the yield reduction may have occurred during many years. Since the drainage duration (> 24 h) was sufficiently long to result in hypoxic conditions affecting plant productivity (Pelletier et al., 2016), even in the faster drainage section of the bed, the drain pipes spacing is probably too wide for adequate drainage and improvement of the drainage design also warrant further investigation.

CONCLUSION

Cranberry is very sensitive to poor drainage conditions. These two cases clearly show that this crop must be grown in beds in which the drainage system is fully effective to avoid cranberry yield losses. In this study, yield losses of 39% were measured when drain pipes were clogged and of 25% due to a faulty design/construction of the drainage outlet. These two cases show that the design and maintenance of a properly functioning drainage system is of prime importance for maximizing yield and, therefore, warrants a close follow-up with appropriate equipment and access structure.

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160 **Fig. 1.** The swollen masses found at the drain outlet after pumping water at low operating
161 pressure (300 kPa) in drain pipes for washing.

Fig. 2. Monitoring the development of cranberries growing over drain pipes clogged with swollen masses from June 7 to August 17 2012. Drain pipes were washed on June 7.

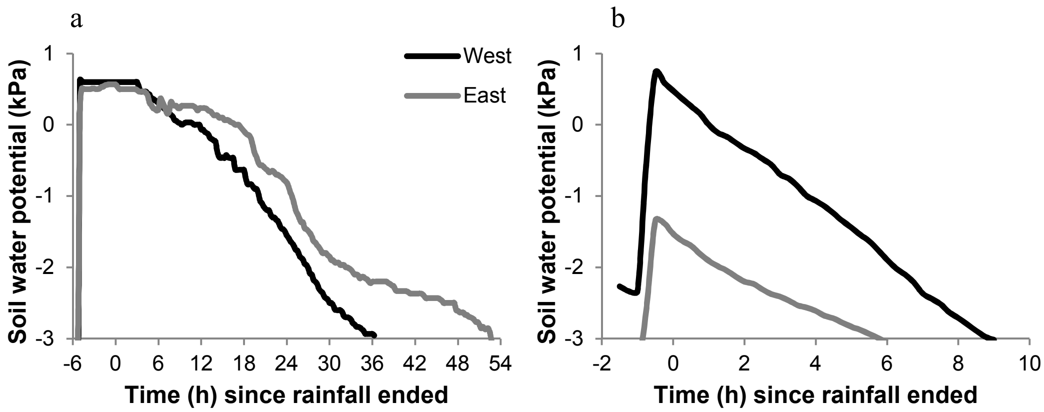

Fig. 3. Temporal variations of soil water potential values after the end of rainfall (time=0) until it returns to the target of -3 kPa in both section (West vs East) of a cranberry bed. In a) rainfall was 29 mm; the depth of the drainage outlet was problematic at the West extremity of the bed and in b) rainfall was 26 mm; the problem was corrected.