Chemical Characteristics of Water Used for Cranberry Production

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ADDITIONAL INDEX WORDS. **alkalinity, *Vaccinium macrocarpon*, water quality, sodium adsorption ratio, soluble salts**

SUMMARY. Since up to 2.4 m (8 ft) of water may be applied annually to cranberry beds for various production purposes, water quality can alter soil chemical properties and potentially affect plant health. Many cranberry plantings have recently been developed in nontraditional production regions and on atypical sites, where

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chemical properties of the available water may differ from those in cranberry sites in the traditional production regions. Water currently being used for cranberry production was sampled from farms in most major production regions to characterize its chemical characteristics. High alkalinity in many samples was a concern, since alkalinity can increase soil pH above the desired level for cranberries. Total soluble salt concentrations and sodium adsorption ratios were seldom high enough to be of concern. Water samples from long-established plantings were lower in

alkalinity, pH, and soluble salt concentrations than samples from newer plantings without production histories.

The quality of irrigation water is particularly important in cranberry (*Vaccinium macrocarpon* Ait.) production since up to 2.4 m (8 ft) of water may be applied annually (Sandler, 1997). Water is applied with sprinkler irrigation systems or by flooding, when the plants are submerged for protection

from winter weather or for water harvesting. The water quality parameters most often of concern in crop production are 1) total salt concentration as measured by electrical conductivity, 2) concentration of sodium (Na) relative to other ions, 3) alkalinity, and 4) borate, fluoride, or other ions in concentrations that are phytotoxic. The detrimental effects of high salt concentrations resulting from salt water intrusion into coastal cranberry beds was documented (Chandler and DeMoranville, 1959). Water alkalinity

Table 1. Locations, sources and sample numbers, and sampling times and handling, for water samples collected from cranberry plantings.

**Location,
sampling time and
sample handling,
and
sources
(sample numbers)**

British Columbia

September. Frozen from 3 d of collection until analysis.

Reservoirs in Delta (2), East and West Richmond (4), Fort Langley (2), Langley (1), and Pitt Meadows (2).

Chile

September. Nonrefrigerated transit for 22 to 24 d before analysis.

Properties of Cran Chile near Valdivia (5).

Maine

August. Frozen from 3 d of collection until analysis.

Adroscoggin County stream (1). Reservoirs in Kennebec (1), Lincoln (1), and Washington (11) Counties.

Massachusetts

March to August. Frozen from 3 d of collection until analysis.

Plymouth County streams and rivers (20) and ponds and reservoirs (18). Barnstable County streams and rivers (6) and ponds (5).

Michigan

August to October. Frozen from 3 d of collection until analysis.

Reservoirs in Allegan (1), Cheboygan (1), Chipewa (1), Ottawa (1), and VanBuren (4) Counties.

New Jersey

July. Frozen from 3 d of collection until analysis

Atlantic County stream (1). Burlington County streams and rivers (12), drain (1), and lake (1). Camden County river (1). Ocean County streams and rivers (3).

Quebec

August. Nonrefrigerated transit for 3–5 d before analysis.

Irrigation canal (1), reservoirs (5), and rivers (2) near St-Louis-de-Blandford. Irrigation canal (1) and reservoirs (2) near Notre-Dame-de-Lourdes.

Washington

October to November. Nonrefrigerated transit for 4 d or frozen until analysis.

Reservoirs and ponds recharged with groundwater in Grayland (5), Long Beach (5), and North Beach (2).

Wisconsin

May to August. Nonrefrigerated transit for 3–5 d until analysis.

Various sources in Adams (1), Jackson (1) Juneau (2), Portage (1), Vilas (3), and Wood (13) counties. Monroe County ponds and reservoirs (3) and ditches (2). Oneida County ponds (2).

refers to the presence of carbonates and other ions capable of neutralizing acids. The hazard from alkaline water was recognized several decades ago after the diversion of alkaline water into cranberry beds rendered a successful production area in Wisconsin non-profitable (Stevens, 1946a; Stevens et al., 1940). Cranberries require acidic soils (optimum range 4.5 to 5.0), and alkaline water apparently increased soil pH beyond this range. Korcak (1989) suggested that acid-loving plants such as cranberries may be inhibited by high soil pH or the high calcium (Ca) levels usually present in these soils. Since most of the alkalinity in natural waters is contributed by Ca carbonate (Brocks et al., 1993), the Ca present in alkaline water may also be hazardous to cranberries. Extremely low carbonate (alkalinity) levels may increase the risk that oxygen deficiency will occur if plants are flooded during warm sunny days (Stevens and Thompson, 1942).

Until recently, commercial cranberry culture had been practiced on acidic hydric soils in Massachusetts, New Jersey, Oregon, Washington, Wisconsin, and the Canadian province of British Columbia. Surveys in the 1940s indicated that water used on Massachusetts cranberry plantings was very low in alkalinity [1 to 6 mg·L⁻¹ (ppm) bound CO₂] and acidic to neutral in pH, whereas water from Wisconsin operations was usually higher in alkalinity (5 to 80 mg·L⁻¹ bound CO₂) and pH

(Stevens, 1946b). Water from New Jersey cranberry farms was described as very low in alkalinity (Stevens et al., 1940).

Strong demand for cranberries in the early 1990s encouraged the establishment of cranberry plantings in new regions such as Maine, Michigan, Minnesota, and New York in the United States, the Canadian Provinces of Quebec, Nova Scotia, and New Brunswick, and in Chile and some Eastern European countries. Where the traditional acidic, hydric soils are limited or protected from development by land-use policies or regulations, new plantings have been built on upland sites (Roper and Planer, 1993). New plantings may represent more diverse soil and water characteristics than were associated with the traditional production sites. This survey was conducted to describe the range of chemical properties of water sources currently being used for cranberry production. The information may be useful to individuals evaluating the potential of new sites and water sources for cranberry production.

Materials and methods

Samples were collected between March and November 1998, from the edge of streams and rivers above or below cranberry operations, and the surface of ponds, lakes and reservoirs that served as water sources for cranberries (Table 1). Water was placed in high-density polyethylene or glass bottles and

sent to the Michigan State University Soil and Plant Nutrient Laboratory for analysis. Analyses included Ca, K, Mg, and Na (atomic absorption/emission), chloride (chloride electrode), total alkalinity expressed as CaCO₃ equivalent (Alkalinity Test Kit, LeMott Chemical Products Co., Chestertown, Md.), soluble salts (conductivity cell) and pH (pH electrode). The sodium adsorption ratio (SAR) was calculated as described by Wilcox and Durum (1967) as a measure of sodium hazard: $SAR = Na / \div ((Ca + Mg) / 2)$, where concentrations are expressed as meq·L⁻¹.

Because the time between sampling and analysis varied, 15 samples were analyzed immediately after collection and again after 4 to 6 weeks of storage at 18 °C (64.4 °F). Selected samples represented a range in pH and alkalinity levels. A *t* test was used to compare water quality parameters before and after storage.

Results and discussion

The mean pH of water samples was lowest in New Jersey (5.2) and Massachusetts (6.1) and highest in Michigan (7.7), Chile (7.4) and Washington (7.4) (Table 2). The range and mean pH levels for Massachusetts (range, 4.0 to 6.9; mean, 6.1) and Wisconsin samples (range, 6.2 to 8.0; mean, 7.0) compare closely with values recorded by Stevens (1946b) over 50 years ago in Massachusetts (range, 4.2 to 7.5; mean, 6.1) and Wisconsin (range, 4.2 to 8.7; mean,

Table 2. Mean and range (in parentheses) of selected chemical properties of cranberry water samples.

Region	Sample no.	Alkalinity		Chemical					Soluble salts	
		pH	(mg·L ⁻¹ CaCO ₃)	K	Ca	Mg	Na	Cl	(dS·m ⁻¹)	SAR ^z
British Columbia	11	6.9	40	6	36	7	42	83	0.28	1.6
		(6.5–7.3)	(16–61)	(1–9)	(0–160)	(3–21)	(5–162)	(17–354)	(0.11–1.05)	(0.3–4.0)
Chile	5	7.4	26	2	27	2	5	13	0.05	0.3
		(7.2–7.9)	(17–32)	(1–3)	(21–32)	(0–2)	(5–7)	(5–19)	(0.02–0.07)	(0.2–0.3)
Maine	14	7.0	31	2	11	1	10	14	0.13	0.9
		(5.3–7.4)	(17–56)	(0–6)	(0–40)	(0–9)	(5–24)	(3–48)	(0.03–0.34)	(0.3–1.2)
Massachusetts	50	6.1	18	1	16	2	12	21	0.12	0.7
		(4.0–6.9)	(9–44)	(1–4)	(9–67)	(0–3)	(0–46)	(0–80)	(0.05–0.34)	(0.0–1.8)
Michigan	8	7.7	105	5	66	11	4	16	0.32	0.2
		(6.9–8.1)	(32–190)	(2–12)	(20–133)	(1–20)	(0–8)	(0–38)	(0.11–0.58)	(0.0–0.3)
New Jersey	19	5.2	14	0	2	0	6	6	0.05	0.1
		(4.5–7.1)	(8–40)	(0–2)	(0–18)	(0–1)	(4–13)	(2–22)	(0.03–0.12)	(0.0–1.6)
Quebec	11	7.0	46	4	34	1	0	0	0.15	0.0
		(4.9–7.6)	(16–116)	(0–15)	(10–57)	(0–3)	(0–0)	(0–0)	(0.02–0.31)	(0.0–0.0)
Washington	12	7.4	53	3	10	5	18	36	0.20	0.8
		(6.8–7.9)	(18–116)	(1–6)	(0–50)	(0–14)	(4–49)	(14–80)	(0.07–0.33)	(0.0–1.9)
Wisconsin	28	7.0	40	2	15	3	10	22	0.14	0.8
		(6.2–8.0)	(16–128)	(1–7)	(0–80)	(1–20)	(2–69)	(3–126)	(0.02–0.46)	(0.0–2.1)

^zSAR is the sodium adsorption ratio.

Fig. 1. Relationship between the pH and alkalinity levels of water samples collected from various cranberry production regions.

6.4). Mean alkalinity levels were lowest in New Jersey (14 mg·L⁻¹ CaCO₃ equivalent) and Massachusetts (18), and highest in Michigan (105). In previous surveys, water from Wisconsin cranberries exhibited a higher mean alkalinity, and a wider range, than water from Massachusetts plantings (Stevens, 1946b), but a direct comparison with data in this study is difficult because the conversion of the alkalinity units used earlier (bound carbon dioxide) to the units used in our study is not clear.

The primary problem with the use of alkaline irrigation water is that soil pH may be increased above desired levels (Hull and Stevens, 1944; Hanson and Stein, 1999), resulting in increased weed competition and re-

duced berry production (Stevens, 1946b). However, suitable water alkalinity and pH levels for cranberry production are not established. Based on observations in Massachusetts and Wisconsin, Stevens et al. (1940) advised against cranberry production where water pH is above 7.0. This rule needs to be qualified when considering water from more diverse geographic regions, since several

samples in this survey with a pH above 7.0 contained relatively low alkalinity levels (Fig. 1).

Water alkalinity levels are more significant than pH, since it is alkalinity, not water pH, that affects soil pH (Argo and Biernbaum, 1996). Growers can conveniently monitor water pH with moderately priced pH meters, or measure alkalinity with inexpensive test kits. Alkalinity levels were consistently low (<50 mg·L⁻¹ CaCO₃) when pH was below 6.8, but varied from 20 to 180 mg·L⁻¹ when pH was above 7.0 (Fig. 1). These data indicate that reasonably low alkalinity levels (<50 mg·L⁻¹) can be expected if pH is below neutral, but a pH above 7.0 is not a reliable predictor of alkalinity levels. It should be cautioned that the pH of surface waters is more variable over time than alkalinity, and may change as much as two units between years (Stevens et al., 1940).

The hazard associated with alka-

line water may depend partly on management practices and soil characteristics. Water alkalinity is expected to have a greater effect on soil pH when high irrigation rates are applied to sandy soils with low buffering capacities. Sulfur and, to a lesser extent, aluminum sulfate and sulfuric acid are commonly used today to lower soil pH, and can theoretically be used to counteract the effects of alkaline water on soil pH. It is not clear whether acidifying agents were used in an attempt to maintain proper pH levels in beds adversely affected by alkaline water (Stevens et al., 1940). A useful rule of thumb in estimating acidification requirements is that an acre-foot or 1,234 m³ (326,000 gal) of water with an alkalinity level of 100 mg·L⁻¹ CaCO₃ contains the equivalent of about 123 kg (270 lb) of lime. About 39 kg (86 lb) sulfur or 68 L (18 gal) of concentrated sulfuric acid would be needed to neutralize 123 kg (270 lb) of lime. Since up to 2.4 m of water may be applied annually to cranberries, acidification agents can represent a significant annual production cost where water alkalinity is high.

The amount of acidification required to counteract the effects of alkaline water may also depend on the bed design and water management. The majority of flood water applied for harvesting and winter protection often is removed by surface drainage and does not percolate through the soil. This water would likely have less effect on soil pH than water that percolates into the soil, such as that applied as

Table 3 . Effect of storage for 4 to 6 weeks on chemical characteristics of selected cranberry water sources.

Group	Stored	pH	Soluble salts (dS·m ⁻¹)	Chemical (mg·L ⁻¹)					Alkalinity (mg·L ⁻¹ CaCO ₃)
				K	Ca	Mg	Na	Cl	
Acidic samples (n = 8)									
	No	6.81	0.12	2.3	14	1.3	10	25	27
	Yes	6.74	0.14	2.8	25	2.5	10	28	29
Alkaline samples (n = 7)									
	No	7.71	0.30	2.9	43	8.6	17	35	91
	Yes	7.51	0.35	2.7	44	11.4	17	52	87
All samples (n = 15)									
	No	7.23	0.20	2.5	27	4.7	14	30	57
	Yes	7.10	0.24	2.7	34	6.7	13	39	56
Effect of storage									
Acidic samples		NS	NS	NS	NS	NS	NS	NS	NS
Alkaline samples		NS	NS	NS	NS	NS	NS	NS	NS
All samples		NS	*	NS	NS	NS	NS	NS	NS

NS, *Nonsignificant or significant F value at $P < 0.05$.

sprinkler irrigation during the growing season. Flood water may have a greater effect on soil pH in beds designed with subsurface drains only. Less acidifying agents may be needed if cranberry systems are designed to capture and reuse drain water. Water alkalinity levels were reduced when water percolated through acidic soils or if water had been treated directly with acid before application (Hanson and Stein, 1999).

Total soluble salt levels ranged from 0.02 to 1.05 dS·m⁻¹ (Table 2). The salinity hazard of irrigation water is classified as low for most crops if the soluble salt content is <0.25 dS·m⁻¹, and levels above 0.75 dS·m⁻¹ are considered to present a high hazard (Wilcox and Durum, 1967). Of the 158 total samples, 142 contained soluble salt levels below 0.25 dS·m⁻¹ (low salinity hazard). Only two samples had total salt levels considered to be potentially limiting for crop growth, and these came from British Columbia. These samples had soluble salt levels of 0.81 and 1.05 dS·m⁻¹, and also contained relatively high levels of Na (138, 192 mg·L⁻¹) and Cl (323, 354 mg·L⁻¹). These samples were collected at the end of an abnormally dry summer, and the high Na and Cl levels likely resulted from a temporary intrusion of sea water into the irrigation supplies.

Based on general agricultural irrigation standards (Wilcox and Durum, 1967), the sodium hazard was found to be low in all samples, as indicated by the Na concentration and the sodium adsorption ratio (SAR) (Table 2). Sodium hazard is a function of the SAR and total soluble salt levels. At the soluble salt levels in these samples, SAR values below about 5 would be considered safe for most crops. SAR values ranged from 0 to 4.0, and the only samples with values above 2.1 were the aforementioned samples from British Columbia.

Sample handling and duration between collection and analysis varied in this survey. To test whether chemical properties changed if analysis was delayed, groups of low pH samples (n = 8) and high pH samples (n = 7) were analyzed shortly after collection, and again after 4 to 6 weeks of storage at 18 °C. The only parameter affected significantly by storage was soluble salts, which was increased (Table 3). This suggests that variations in the time between sampling and analysis would

have little effect on analytical results. When analysis was delayed more than 14 days, samples were frozen.

Water quality characteristics in this survey may have been affected by sampling dates (Table 1). Samples from each region were collected at different times, and those from some regions (Massachusetts) were collected over a period of as much as six months. The pH of Wisconsin lakes is known to vary with time of year, whereas alkalinity levels are generally more stable (Birge and Juday, 1911). Precipitation patterns likely varied with region and time, and could have affected the chemical properties of surface waters.

The water sources associated with recently developed cranberry plantings appear to reflect a wider range in some chemical properties than water from older production regions. A total of 104 samples were associated with older cranberry plantings with a history of more than 10 years of production, whereas 51 samples were associated with plantings developed within the last 10 years that have limited production histories. Samples associated with newer plantings included all those from Chile, Maine, and Quebec were, and selected samples from British Columbia (5 samples), Massachusetts (3), Michigan (7), and Wisconsin (6). As a group, samples from newer plantings had a higher mean pH (7.2), soluble salts (0.19 dS·m⁻¹), and alkalinity (50 mg·L⁻¹ CaCO₃) than samples from established plantings (pH 6.3, soluble salts 0.12 dS·m⁻¹, alkalinity 25 mg·L⁻¹ CaCO₃).

Conclusions

The results of this survey were used to describe the range in chemical properties of water sources currently used for cranberry production. Alkalinity was the only parameter that was frequently outside the accepted ideal range for cranberries. Alkalinity levels appeared to be high enough in many samples to impact soil pH, and require applications of acidifying materials to maintain the acidic soil conditions required by cranberries. Few samples appeared to contain total soluble salts or SAR values high enough to impact plant health or production. Samples from older production areas with a history of successful production were generally lower in pH, alkalinity, and soluble salts than those from recently developed plantings without a proven production record.

Literature cited

- Argo, W.R. and J.A. Biernbaum. 1996. The effect of lime, irrigation-water source, and water-soluble fertilizer on the pH and macronutrient management of container root media with impatiens. *J. Amer. Soc. Hort. Sci.* 121:442-452.
- Birge, E.A. and C. Juday. 1911. The inland lakes of Wisconsin. *Wis. Geol. Nat. Hist. Serv. Bul.* 22 (as cited in Stevens et al., 1940).
- Brocksen, R.W., M.D. Marcus, and H. Olen. 1993. Practical guide to managing acidic surface waters and their fisheries. Lewis Publ., Boca Raton, Fla.
- Chandler, F.B. and I.E. DeMoranville. 1959. The harmful effect of salt on cranberry bogs. *Univ. Mass. Expt. Sta. Misc. Publ.* 1007.
- Hanson, E.J. and A. Stein. 1999. Effects of water use on the chemical characteristics of cranberry soils. *J. Plant Nutr.* 22:427-434.
- Hull, H.H. and N.E. Stevens. 1944. Changes in pH and in base-exchange properties of cranberry soils following the use of alkaline water. *Soil Sci.* 58:405-408.
- Korcak, R.F. 1989. Variation in nutrient requirements of blueberries and other calicifuges. *HortScience* 24:573-578.
- Roper, T.R. and T.D. Planer. 1993. Upland cranberry plantings in Wisconsin, thoughts on creating the appropriate agronomic conditions. *Cranberries Mag.* 57(7):4,18.
- Sandler, H.A. (ed.). 1997. Massachusetts cranberry production guide an information guide. *Univ. Mass. Cranberry Expt. Sta., East Wareham, Mass., Ext. Publ.* SP-127.
- Stevens, N.E. 1946a. Further observations on alkaline flooding water in cranberry growing. *Trans. Wisc. Acad. Sci.* 36:395-398.
- Stevens, N.E. 1946b. Observations on flooding water used in cranberry culture. *Mass. Expt. Sta. Bul.* 433:37-48.
- Stevens, N.E. and N.F. Thompson. 1942. Factors influencing injury to cranberry plants during flooding. *Trans. Wisc. Acad. Sci.* 34:73-81.
- Stevens, N.E., L.M. Rogers, and H.F. Bain. 1940. Alkaline flooding water in cranberry growing. *Trans. Wisc. Acad. Sci.* 32:351-360.
- Wilcox, L.V., and W.H. Durum. 1967. Quality of irrigation water, p. 104-122. In: R.M. Hagan, H.R. Haise, and T.W. Edminster (eds.). *Irrigation of agricultural lands*. Amer. Soc. Agron. Monogr. 11.