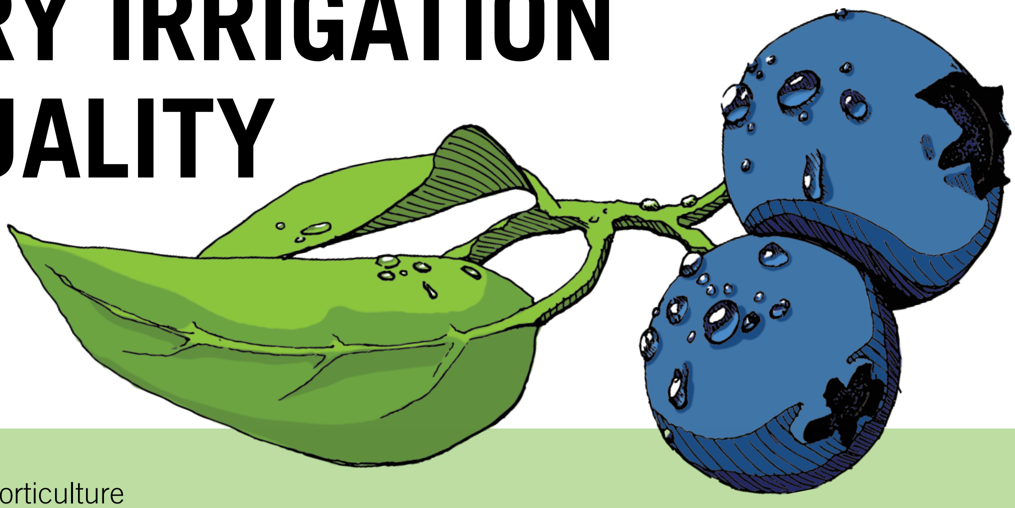
BLUEBERRY IRRIGATION WATER QUALITY



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Blueberry plants are sensitive to water pH, salinity, chloride, boron, and sodium. These fruits thrive in acidic soil with a pH of 4.0 to 5.5, and irrigation water quality can have a significant impact on production. Test water quality before planting to determine whether the water is suitable for plant growth and production. See Table 1 for a list of water quality parameters that should be included in a water test for blueberry production.

Table 1. A. Salts, comprised of anions (negatively charged ions) and cations (positively charged ions) found in irrigation water, and B. Water tests that characterize irrigation water quality.

Salts			
Anions		**Cations**	
Bicarbonate	HCO_3^-	Calcium	Ca^{2+}
Boron	B	Magnesium	Mg^{2+}
Carbonate	CO_3^{2-}	Potassium	K^+
Chloride	Cl^-	Sodium	Na^+
Nitrate	NO_3^-	Manganese	Mn^{+2}
Sulfate	SO_4^{2-}	Iron	Fe^{+2}

Water Quality Parameters	
Total dissolved solids or electrical conductivity	TDS or EC
Residual sodium carbonate	RSC
Lime deposition potential	DP
Sodium adsorption ratio or sodium hazard	SAR
Acidity/alkalinity	pH

Georgia's commercial blueberry production is primarily located in the southeastern portion of the state. This region is above the Floridan aquifer, which consists of limestone caverns where groundwater may flow freely. Private wells generally draw water from the upper Floridan aquifer, where large volumes of water travel through the limestone with significant amounts of dissolved minerals. In areas where large volumes of water are moving in and out of the aquifer, the resulting concentration of dissolved minerals can be low. Conversely, in close proximity to saltwater or areas of low water infiltration, the levels of dissolved minerals increase. Counties bordering the Atlantic coast can have much higher concentrations of dissolved minerals. As limestone affects pH, irrigation water drawn from the upper Floridan aquifer can have pH 7.0 or greater.

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In some instances, surface water is used for irrigation. The most common surface water used for irrigation is from reservoirs that are dug on the farm to collect rainwater, surface runoff, and/or replenishment from wells. These water sources also should be tested periodically to ensure required or expected quality. In addition to the tests from Table 1, analyses of other contaminants may be necessary if microbiological organisms (*E. coli*, salmonella, listeria, etc.), pesticides, herbicides, or fuel oils may have been introduced into the irrigation water. Bacterial contamination is an especially important consideration if manure has been applied to the crop or if any manure runoff is suspected from nearby production facilities.

Blueberry plants have a shallow root system and water availability to the roots can be dramatically affected by soil type, soil permeability, and mulch. Sandy soils have greater permeability and water can move through the profile quickly. However, mulches provide ground cover, which can reduce evaporation of water from soil surfaces. Transpiration (evaporation of water from leaf surfaces) also is an avenue of soil moisture loss. Depending on location and weather (temperature, humidity, and cloud cover can have effects on rates of evapotranspiration), a mature blueberry bush can use 2–3 gallons of water per day. Blueberry plants' shallow root systems will be negatively affected if the quality of water being delivered has high concentrations of salts, excessive pH, or other extremes in water quality characteristics listed in Table 2. Water that exceeds upper limits may need to be treated, if possible.

Table 2. Upper limits of water quality that suggest corrective action or prohibition of blueberry production.

Test	Upper Limit
Electrical conductivity (EC) or salinity	1000 µS/cm (or µmhos/cm) or 1.0 dS/m (or mmhos/cm)[a]
Total dissolved solids (TDS)	640 ppm or mg/L[b]
pH (acidity/alkalinity)	6.0[c]
Bicarbonate (HCO_3^-)	92 ppm or mg/L[d]
Boron (B)	1 ppm or mg/L[d]
Chloride (Cl^-)	70 ppm or mg/L[d]
Sodium (Na^+)	46 ppm or mg/L[d]

[a]Ireland & Wilk, 2006; Himelrick & Curtis, 1999; recommended level for EC.
[b]Based on conversion calculation of EC to TDS (EC < 5 dS/m x 640 = ppm).
[c]Suggested to acidify irrigation water if 6.0 pH or above.
[d]Retamales & Hancock, 2012.

SALTS

Salts are a combination of positively charged elements (cations) and negatively charged elements (anions). Commonly, salt is thought of as sodium chloride (NaCl) or table salt; however, salts come in many cations and anions that exist in water. Table 1 includes a list of common anions and cations that can affect crop production. Salt accumulation happens when inputs exceed outputs. Input or accumulation is derived from salts in the irrigation water, breakdown of the soil parent material, fertilization, compost application, and any other amendments. Output or removal of salts happens through leaching and crop removal. If irrigation water is high in salt content, then leaching is the only effective way to remove the salts. Blueberry plants are extremely sensitive to salt; therefore, high salt content in the soil will reduce water uptake, desiccate the plant, cause leaf burn (Figure 1), reduce yields, and diminish fruit quality.

Salinity is the measure of all the salts dissolved in water and expressed as electrical conductivity (EC) or total dissolved solids (TDS). Blueberry's sensitivity to salt is shown in Table 2. If we consider the upper limit of EC for blueberry, an EC of 1.0 dS/m contains 640 ppm salt (640 [conversion factor for EC < 5 dS/m] x 1.0 = 640 ppm). When irrigating at a rate of 3 acre-feet per year, approximately 2.6 tons per acre of salt has been applied according to the following calculation:

$$\frac{\text{640 ppm salt x 2.7 (million pounds water per acre-foot) x 3 acre-feet}}{\text{2000 lb per ton}} = \text{2.6 tons of salt per acre}$$

Salt management of irrigation water is neither cost effective nor practical. Even leaching of salt from the soil with tremendous volumes of water can be detrimental to blueberry plants because of increased potential for root-infecting diseases like *Phytophthora cinnamoni*. Blueberry plants thrive in well-drained soils, but are sensitive to drought, so irrigation must be carefully managed to achieve high production levels.

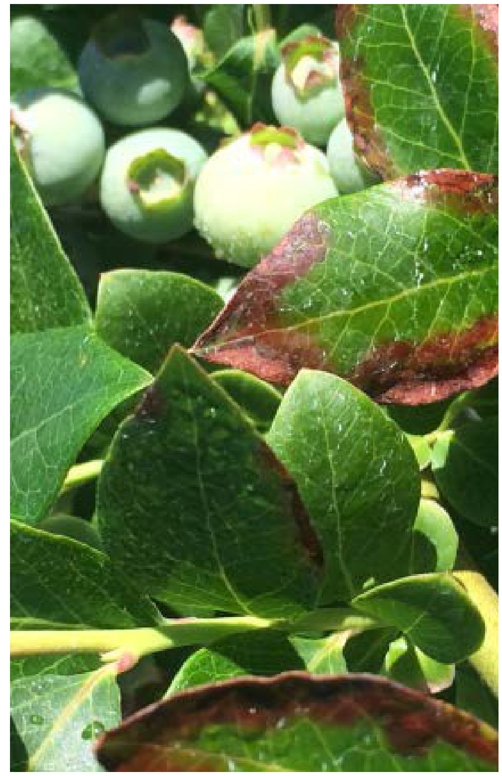

Figure 1. Salt burn in southern highbush blueberry 'Farthing'.
Photo: Joseph Slusher.

SALT COMPOSITION IN IRRIGATION WATER

As noted in Table 2, particularly high levels of an anion or cation can inhibit crop production. Close attention should be given to chloride, sodium, boron, carbonate and bicarbonate, calcium, and magnesium levels. From the water analysis, you can calculate residual sodium carbonate (RSC), lime deposition potential (LDP), and sodium adsorption ratio (SAR) or sodium hazard.

Boron is toxic to many crops, including blueberry. Concentrations of boron in irrigation water exceeding 1 ppm will damage blueberries and should not be used as irrigation water. In high concentrations, boron shows very similar symptoms to its deficiency, where cankers form on canes and shoots die back without wilting. The recommended annual application of boron should not exceed 8 oz/acre in split applications, and the amount applied is dependent on leaf tissue analysis. Irrigating with water containing 1 ppm boron will deliver 8.1 lb of boron in a year, which is 16 times the maximum application rate.

Chloride in excess can lead to leaf burn if overhead irrigation is used and if taken up by the plant in excess. However, chloride is an essential plant nutrient and the plant should be productive if water analysis is less than 70 ppm.

Sodium is of concern because it can affect soil structure. Continued use of irrigation water with sodium in excess of calcium and magnesium leads to a very tight soil structure with poor water infiltration, poor aeration, and increased surface crusting. This soil hardening restricts root growth and makes tillage difficult. To evaluate the potential for soil hardening by sodium, an equation can be used to predict the sodium hazard or sodium adsorption ratio (SAR):

$$SAR = \frac{[Na^+]}{\sqrt{0.5([Ca^{2+}] + [Mg^{2+}])}}$$

SAR equals the sodium concentration (meq/L) divided by the square root of the half-sum of calcium plus magnesium concentrations (meq/L). See appendix A for conversions of ppm (or mg/L) to meq/L. SAR alone is only one calculation that will help predict the effect of irrigation water on soil. Other analyses of water quality will form a broader picture. For example, evaluate the sodium hazard by interpreting EC and SAR (Table 3), as both EC and SAR will affect water infiltration. In general, the sodium hazard increases as SAR increases and EC decreases.

In Table 3, the analyses of EC and SAR are used to evaluate the risk across soil types and are a general guide. The following is an example of how to use Table 3: If a water analysis indicated that SAR equaled 4 and the EC was 1.6 dS/m, from the SAR column go to the 3–6 range and follow it over to the column that reads > 1.2, which is in the low risk column, meaning low sodium hazard.

Table 3. Evaluation of the risk of sodium in irrigation water causing water infiltration problems using both electrical conductivity (EC) and sodium adsorption ratio (SAR) as an estimators.

SAR	Low Risk	Moderate Risk	High Risk
	Electrical conductivity (EC_w) measured as dS/m		
0–3	> 0.7	0.7–0.2	< 0.2
3–6	> 1.2	1.2–0.3	< 0.3
6–12	> 1.9	1.9–0.5	< 0.5
12–20	> 2.9	2.9–1.3	< 1.3
20–40	> 5.0	5.0–2.9	< 2.9

From Ayers & Westcot, 1985.

Residual sodium carbonate (RSC) is another calculation that can predict sodium hazard (Table 4). The calculation is straightforward: it is the sum of the carbonates (bicarbonate + carbonate) subtracted by the sum of the divalent cations (calcium and magnesium):

$$(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) = RSC$$

In calculating the RSC, all water analysis units are meq/L. See appendix A for conversions of ppm (or mg/L) to meq/L. Rising RSC, above zero, is directly related to increasing sodium hazard to the soil. Positive RSC values indicate that calcium is lost through a chemical reaction resulting in the formation of calcium carbonate, which will increase soil pH. Table 4 has some suggested limits and actions as RSC increases above zero. Generally, water with an RSC above 1.0 will require monitoring of water infiltration and soil pH, and corrective action may be required. There are two methods for correcting RSC: adding acid or adding gypsum to the irrigation water. For blueberry, adding gypsum can increase the lime deposition potential (LDP) and is not recommended. However, acid additions are common for irrigation water being supplied to blueberry. Because much of the irrigation water is well water from limestone aquifers, acidification is generally corrected to a level of 5.5 pH. Adding acid to water with a pH of 7.0 will change a positive RSC to negative RSC. In most irrigated blueberries the RSC will not be of concern; however, sodium hazard is not reduced by acid addition and should be considered when establishing blueberries.

Lime deposition potential (LDP) is an indicator used to evaluate whether lime deposition could happen through precipitation of calcium or magnesium carbonates (lime) out of the irrigation water, which leaves white

Table 4. Suggested limits for irrigation water based on residual sodium carbonate (RSC).

RSC Classification	RSC Sum (meq/L)	RSC Irrigation Hazard
Low	Below 0	No RSC- associated problems.
Medium	0–1.0	Monitor infiltration and soil pH; amendment may or may not be necessary; check SAR.
High	1.0–2.5	Monitor infiltration and soil pH; amendment with acid likely necessary.
Very High	Above 2.5	Monitor infiltration and soil pH; amendment with acid necessary.

From Stevens, 1994.

residues or deposits. Factors affecting lime deposition are higher temperatures, higher pH, loss of carbon dioxide in the water, and evaporation. As water passes through the irrigation system, any of these environmental effects can cause deposition on the equipment, vegetation, and fruit.

Lime deposition is a problem for growers drawing irrigation from the Floridan aquifer. Lime will deposit in the irrigation distribution system causing clogging of components, especially drip emitters. Drip or microirrigation systems are prone to problems from clogging. If irrigating with an overhead system, lime residues can reduce marketability of fruit because the white residues are often associated with pesticides. If fertigating with irrigation water of high lime concentrations, nutrients can precipitate within the system, not be available to the plants, and plug emitters. Irrigation water with high concentrations of lime can increase soil pH and reduce solubility and availability of phosphorous, zinc, and iron.

To calculate lime deposition potential of irrigation water, use a similar equation as SAR. However, bicarbonate + carbonate are compared to calcium + magnesium; the number that is the least is the LDP.

LDP is the lower number between the following two calculations:

$$(HCO_3^- + CO_3^{2-}) \text{ or } (Ca^{2+} + Mg^{2+}) = \text{LDP in meq/L}$$

For example, if:

- HCO_3^- = 4 meq/L
- CO_3^{2-} = 1 meq/L
- Ca^{2+} = 2 meq/L
- Mg^{2+} = 1 meq/L

Then,

$(HCO_3^- + CO_3^{2-}) = 4 + 1 = 5$ meq/L

$(Ca^{2+} + Mg^{2+}) = 2 + 1 = 3$ meq/L

So, LDP = 3 meq/L (the lower one of the two)

Table 5 provides some useful guidelines for overhead application rates of irrigation water with different lime deposition potentials (LDPs). The application rates are especially important for growers using pivot and overhead irrigation to minimize lime deposits on blueberry fruit.

Table 5. Guidelines for overhead irrigation to avoid lime deposits on the crop.

Lime Deposition Potential (LDP) of Water (meq/L)[a]	Suggested Water Application Rate (inch/hour)
Below 2	No limitations
2-4	More than 0.2
3-4	More than 0.2; irrigate only when evaporation rates are low (nights or cloudy days)
Above 4	Not recommended for overhead irrigation

[a]The amount of lime formed is expressed by the calculation of lime deposition potential: $(HCO_3^- + CO_3^{2-})$ or $(Ca^{2+} + Mg^{2+})$ = LDP in meq/L. The value of LDP is represented by the lower value calculated between bicarbonate + carbonate or calcium + magnesium.
From Stevens, 1994.

Removing lime from irrigation water is a function of lowering pH and alkalinity. Alkalinity is a measure of the water's capacity to neutralize acids. Generally, for waters being drawn from the Floridan aquifer or from natural sources, the majority of the alkalinity is derived from bicarbonates (> 90%; HCO_3^-). However, other anions such as carbonates, hydroxides, phosphates, borates, and silicates can contribute to the total alkalinity to some extent.

In blueberry production, water being used for irrigation can have a tremendous effect on soil pH. Most growers will lower pH of irrigation water to a pH of 5.5 with an acid such as sulfuric acid. The practice of acid injection with sulfuric acid reduces lime residues as acid reacts with the lime to form carbon dioxide and calcium sulfate (gypsum). Further, acidification of the irrigation water forms sulfates of magnesium and sodium. The sulfates are more soluble and less likely to form residues on fruit or clog micro-irrigation systems. Table 6 shows how much sulfuric acid is required to neutralize bicarbonate in irrigation water. Other acids can be used; adjust rates based on acid strength, using product information provided by the supplier. Monitoring irrigation water can be adequately done with test strips that are color sensitive at varying pH levels.

Low volume irrigation such as micro- or drip irrigation (Figure 2) is prone to clogging from several water quality characteristics. Testing before establishing a blueberry orchard can resolve some of the potential problems through water acidification and filtration. A list of characteristics and potential plugging hazards based on concentrations can be seen in Table 7.

Table 6. Amount of sulfuric acid in different concentrations required to neutralize 90% of the bicarbonate in irrigation water.[a]

Bicarbonate in Water		Sulfuric Acid (H_2SO_4 at 95% or 33%) Required per Acre-Inch of Water			
		95%	33%	95%	33%
(mg/L or ppm)	meq/L	lb		gal	
50	0.8	8.6	24.8	0.6	1.7
100	1.6	17.2	49.5	1.1	3.2
200	3.3	34.3	98.7	2.3	6.6
400	6.6	68.7	197.8	4.6	13.2

[a]Additional acid is required to lower pH to 5.5, which will effectively neutralize alkalis.
Adapted from Stroehlein & Halderman, 1975.

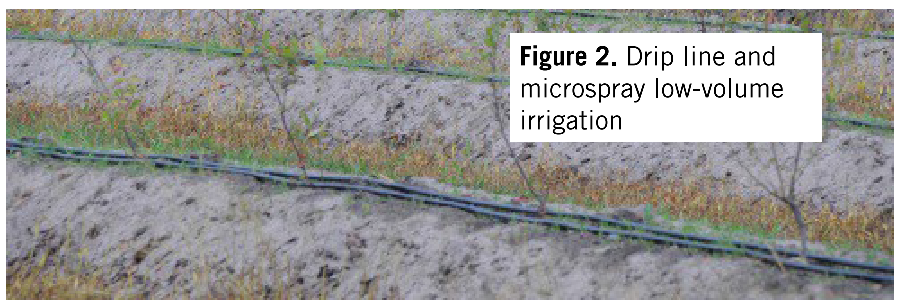

Figure 2. Drip line and microspray low-volume irrigation

Table 7. Plugging potential of irrigation water in micro- or drip irrigation systems.

Factor	Plugging Hazard Based on Level		
	Slight	Moderate	Severe
pH	< 7.0	7.0 to 7.5	> 7.5
Dissolved solids (mg/L)	< 500	500 to 2000	> 2000
Manganese (mg/L)	< 0.1	0.1 to 0.5	> 0.5
Iron (mg/L)	< 0.1	0.1 to 0.5	> 0.5
Hydrogen sulfide (mg/L)	< 0.5	0.5 to 2.0	> 2.0
Hardness (mg/L $CaCO_3$)	< 150	150 to 300	> 300

From Ayers & Westcot, 1985.

CONCLUSIONS

Blueberry plants are shallow-rooted, salt sensitive, and thrive in low soil pH (4.0–5.5). Irrigation of blueberry plants in Georgia is essential for high quality fruit, and the quality of the irrigation water will determine the vigor and quality of fruit harvested. Outlined in this document are critical nutrients and characteristics of blueberry plant irrigation water that should be determined prior to plant establishment. Because well water in Georgia is hard and contains lime, action such as acidification of the water will correct pH and dissolve minerals. However, planting of blueberries should be avoided when toxic levels of chloride, boron, and sodium are present in the irrigation water.

Appendix A

Useful conversion factors for understanding irrigation water quality analysis reports.

Component	Convert from	Multiply By	Convert To
Water mineral or TDS[a]	mg/L	1	ppm
Water mineral or TDS	mg/L or ppm	0.227	lb/acre-inch of water
Water salinity (EC_w)[b]	dS/m	1	mmhos/cm
Water salinity (EC_w)	mmhos/cm	1000	μmhos/cm
Water salinity (EC_w)	dS/m	1000	μmhos/cm
Water salinity (EC_w)	For EC_w < 5 dS/m	640	TDS in mg/L or ppm
Water salinity (EC_w)	For EC_w > 5 dS/m	800	TDS in mg/L or ppm
Calcium content of water	mg/L or ppm	0.0499	meq/L
Magnesium content of water	mg/L or ppm	0.0823	meq/L
Sodium content of water	mg/L or ppm	0.0435	meq/L
Carbonate content of water	mg/L or ppm	0.0167	meq/L
Bicarbonate content of water	mg/L or ppm	0.0163	meq/L
Chloride content of water	mg/L or ppm	0.0282	meq/L
Water NO_{3-}N, SO_{4-}S, B applied	mg/L or ppm	2.72	lb/acre-foot of water
Water NO_{3-}N, SO_{4-}S, B applied	mg/L or ppm	0.227	lb/acre-inch of water
Irrigation Water	acre-inch	27,150	gallons of water

[a]TDS = total dissolved solids in the irrigation water; ppm = parts per million
[b]EC_w = electrical conductivity of the irrigation water
Adapted from Bauder et al., 2007.

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