CRANBERRY IRRIGATION SYSTEM ASSESSMENT SURVEY

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INTRODUCTION

Solid set irrigation systems are an integral component of commercial cranberry production and successful yields depend on the timely application of an appropriate amount of water to satisfy frost protection and crop growth requirements. An irrigation system will perform well if it is engineered correctly and properly operated and maintained (1). Several low technology assessment methods are available to assist the grower or irrigation manager to determine system uniformity, application rate, maintenance demands and system performance. Basic data provided by these tests can be used to calculate immediate irrigation system application dynamics, system efficiencies and estimate annual water use requirements.

The objective of this survey was is to perform basic irrigation system assessments on a representative sample of BC Cranberry Growers Association member irrigation systems. These included: Field Site Irrigation Description and Design; Irrigation Uniformity Measurement; and Sprinkler Nozzle Operating Pressure and orifice measurement. Individual assessment results can be used by the participating farm to assess and modify, if necessary, their irrigation systems. Aggregate results will determine whether increased or more frequent irrigation system assessment should be considered by industry to enhance cranberry water use management and efficiencies.

MATERIALS and METHODS

Field Site Irrigation System Description

Cranberry farms were contacted from across the lower mainland and asked to participate in the irrigation assessment survey. Uniformity assessment was initiated in mid-April 2010 and continued through to just prior to bloom. This was done to reduce the potential impact of walking on cranberry beds at bloom. Some assessments were done during early bloom or later with the growers permission (renovated or new fields included).

A questionnaire describing basic details of the field and design of the irrigation system was prepared. Irrigation system physical attributes not described by the owner or manager were measured and recorded directly by the researcher. Data included: Farm Field Identification; field size; date irrigation system installed; perimeter ditches open or closed; tail water recovery (yes/no); tested irrigation uniformity? (yes/no); sprinkler spacing/pattern/head type/nozzles size; riser height; nozzles replaced? (yes/no); minimum/maximum lateral length; pump operating pressure (psi)/sprinkler operating pressure (psi). Lateral and sprinkler spacing was measured and recorded, as were sprinkler model and nozzle sizes.

Nozzle orifice wear measurement was performed using a drill bit procedure (1,2,3). The shank of a drill bit of similar size diameter of the nozzle is inserted into the nozzle opening while the system is not operating. Conventional wisdom is If the drill bit can be moved 5-10^0 off center, the nozzle is should be replaced.

Irrigation System Uniformity Analysis
Irrigation system uniformity tests were performed using the procedure outlined in the *BC Irrigation System Assessment Guide* (7). The Guide suggests using catch cans in multiples of 4 so that the lowest quartile can be easily determined. Catch cans were placed in two plots during irrigation uniformity measurement in a single cranberry field. Each plot consisted of 36 catch cans spaced in a tape measured 3.8 m x 3.8m (12.5 ft. x 12.5 ft.) grid pattern perpendicular to the direction of lateral movement between two irrigation laterals. One plot was close to the source irrigation pump and the other plot was the furthest possible removed from the source irrigation pump. Plot placement was selected to ensure freedom from edge sprinkler spray overlap or shortened end sprinkler spacing effects.

Catch cans utilized during uniformity measurements consisted of 500 ml (16 oz) red plastic stacking cups, chosen for their convenient size, durability, low cost and visibility. Individual catch cans were stabilized in an upright position, top level with the ground within the crop or on the soil surface using 2 ft. (61 cm) pieces of 14 gauge wire. The wire was shaped to support the can just below the top rim and allow for approximately 8 in. (20 cm) of wire to extend into the soil and/or crop. On mature fields, catch cans were 'nestled' almost flush in relation the surrounding vegetation. Surrounding vegetation above the catch can was removed to prevent deflection of irrigation water.
Following catch can placement, the irrigation pump was turned on for 1 hour using pressure settings and irrigation sets commonly used by the grower. Pump operating time was confirmed using a second hand wrist watch. Since uniformity measurements were made on systems that had previously been operated, extra time was not required to charge the systems. Pump operating pressure during uniformity measurement was recorded.

Effort was made to install catch cans and complete the hour of irrigation early in the morning during calm conditions. Most field sites exhibited increased air movement by mid morning (9:30-10:00 a.m. on). If field conditions became unsettled or breezy following catch can set up, the uniformity test was postponed until calmer conditions prevailed. On one occasion, uniformity measurement was performed on a calm evening following catch can setup.
In the case of Farm 6, uniformity was measured during very windy conditions. Rather than postpone the assessment for another day, the uniformity was assessed to demonstrate wind effects on uniformity measurements.

All sprinklers on the laterals being tested for uniformity were observed for plugs, rotation characteristics and leaks.

At the completion of one hour of irrigation, the pump was turned off. Water in each catch can was measured using a 50 ml plastic graduated cylinder, marked in 1 ml increments. Levels were recorded on the measurement form in the field.

One uniformity test was conducted during a mild rain event (light precipitation started following catch can placement, prior to starting the irrigation pump). In order to account for the precipitation, a control catch can was placed by the pump house and by the far catch can plot; levels of rain collected in both cups was measured and the average subtracted from final catch can measurements.

Nozzle Pressure Measurements

A minimum of ten sprinkler nozzle pressures were measured in close proximity to the catch can plots close to the pump and furthest from the pump during uniformity measurement. Nozzles spraying over the catch can plots were not measured.

A liquid filled, 0 to 100 psi pressure gauge fitted with a 1/8 diameter Pitot tube was used to measure sprinkler pressure. The tip of the Pitot tube was inserted into the nozzle so as to minimize stream blow-by. All measurements were made in a similar method by the same individual for consistency.

Calculations

Catch can data collected was used for calculations designed to evaluate irrigation system uniformity.

Distribution Uniformity (DU) was calculated using the following formula:

$$DU\ \% = \frac{LQ \times 100}{ACO}$$

Where:

LQ = Lowest Quartile - the average catch can reading for the lowest 25% quartile (mm)

ACO = Average Catch Overall – the average of all catch can readings (mm)

DU is a measurement of the evenness of water application across a field in the lowest quartile (25%) and is expressed as a percentage (7, 8,). From a uniformity standpoint, the goal should be to achieve the highest DU% possible for an irrigation system. It is recommended that sprinkler irrigation systems should have a minimum DU% of 80% (7). National Resources Conservation Service (NRCS) suggest a DU of $\geq$ 75% (4).

However, there are some limiting factors of DU% which suggest using DU% as the sole calculation of system uniformity may not the best method. DU% has typically been used in the past for landscape irrigation audits and the calculation emphasizes under-watered areas in the measured area (9). The focus on under-watered areas is informative for ensuring that crops receive sufficient minimum moisture levels to prevent desiccation. However, emphasizing under-watered areas and failure to consider over-watered areas has implications when considering chemigation. Over-irrigation to compensate for under-watered areas exacerbates the problem of over-application of water in areas already receiving above average uniformity water application. When chemigating, this could result in localized over-application of chemicals and potential crop phytotoxicity (T. Van Der Gulick, pers. com.)

Certified Irrigation Designers routinely use the Christiansen's Coefficient of Uniformity (CU%) calculation when designing agricultural irrigation systems (S. Taylor, pers. com.). Consequently, for the purposes of this survey, CU% was also calculated.

Coefficient of Uniformity (CU) was calculated using the following formula:

$$CU\ \% = 100 \times \left(1 - \frac{ADEV}{ACO}\right)$$

Where:
ADEV = average deviation of all catch can readings from the mean value (mm)
ACO = Average Catch Overall – the average of all catch can readings (mm)

Data collected from an irrigation uniformity test can also be used to calculate the system's irrigation rate.

Precipitation rate = average can reading x 3.66 / test time x catch can entrance area
(in/hr) (mm) (min) (in^2)

RESULTS and DISCUSSION

Field Site Irrigation Description and Design
A total of 12 farms participated in the survey, with 2 farms having 2 separate fields each included in the survey (14 fields total). Farms were represented from the following areas: Pitt Meadows (3), Richmond (5), Delta (2) and Vancouver Island (2).

A summary of field and/or irrigation system age and size of fields participating in the irrigation assessment survey is presented in Table 1.

Irr. System Age (yrs)	Number of Farms/fields	Field Size (ac)
≤ 1	1	20
5	2	18, 23
≤ 10	3	14, 4.43,1.43, 7, 3
≤ 15	3	24, 18, 48
≤ 20	5	28, 18, 17, 6, 30

Table 1. Irrigation system age and field size of survey fields

The age of irrigation systems assessed ranged from newly planted fields in the fall of 2010 to systems 20 years old. Field sizes also varied considerably, ranging from 1.43 acres up to 30 acres in size. Two fields assessed for uniformity were newly planted; one planted in 2008 and the second was still in the process of completing plug planting when assessed. A third established field had undergone renovation two years ago with a revised irrigation system spacing and change of sprinkler head design. The remaining fields assessed were well established, producing cranberry plantings. Field age and irrigation system age are used interchangeably in the survey. One 14 year old, 48 acre field assessed was a collection of five smaller bogs that over a period of four years were merged into to a single, large field. Berms and dykes were removed and irrigation systems were connected to a new pump. A similar expansion involving the consolidation of three fields occurred in Field 3.

Field #	Irr. System Age (yrs)	Riser Spacing (ft)	Riser Height (in)	Pattern	Head type	Nozzle size
1	11	40 x 50	15	H	impact	1/8
2	11	40 x 50	24	Offset	impact	1/8
3	20+	57 x 58	28	Offset	impact	9/64
3a*	2	55 x 55	30	Offset	Rotator	Gold (9/64)
4	18	52.5 x 50	12-24	Offset	impact	1/8
4a	10	40 x 51	24	Offset	impact	1/8
5	14	58 x 60	24	Offset	impact	9/64
6	18	58 x 60	24	Offset	impact	9/64
7	20+	30 x 30	24	Offset	impact	5/64
8	2	50 x 50	18	Sq.	impact	9/64
9	18	60 x 60	30	Offset	impact	9/64
10	10	56 x 52	18-24	Offset	impact	9/64
11	8	40 x 50	18	Offset	impact/Rotator	1/8, R2000
12	<1	60 x 60	27	Offset	impact	9/64

Table 2. Irrigation system age, riser spacing, height, pattern, head type and nozzle size of survey fields
*a- indicates different field on same farm

Riser spacing on assessed fields ranged from the tightest pattern of 30 x 30 ft to a maximum of 60 x 60 ft., with several variations in between. Riser height ranged from 15 to 30 inches, with the majority of risers measuring 24 in. from the soil surface. A riser height of at least 18 in. cranberry bogs is considered optimal (1). Two fields, number 4, 10, had variable riser heights throughout the same field, a practice not recommended for promoting uniformity.

The offset or diamond riser pattern was evident in the majority of the fields surveyed. Two fields differed from the offset majority; one was a rectangular or “H” pattern and the other was a 50 x 50 ft. square grid spacing.

The most prominent type of sprinkler head was a brass impact with brass spoon or wedge, although a few fields were equipped with plastic spoons. Head-type was either Rain Bird or Nelson, with some fields equipped with both brands. Sprinkler nozzle orifice size varied between fields, with a 9/64 in. nozzle orifice being the most common at 57%, followed by the 1/8 in. nozzle at 36% of assessed fields. Field 7 had 5/64 in. nozzle orifices that were utilized in a close 30 x 30 ft. spacing.

Field 3a had Nelson R33 Rotator Gold (9/64) heads installed during a field and irrigation system renovation two years prior. Spacing in this renovated field remained offset but was reduced from a 57 x 58 ft. spacing to a 55 x 55 ft. spacing.
Field 11 had two laterals installed with Nelson R2000WF Red (1/8) heads; the remainder of the laterals were fitted with brass impact, 1/8 in. nozzle sprinkler heads.

Uniformity Testing

When growers were asked if they had tested the uniformity of their irrigation systems, one grower responded positively that it had been done in the past. This means that 92% of farms surveyed have never tested their irrigation system's uniformity. Although this predisposition to non-testing may be cause for concern, the nature of the cranberry industry and its development should be taken into consideration. Cranberry irrigation systems in BC are designed after industry standards and protocols that are commonly found in Wisconsin and Massachusetts which have a long history of commercial cranberry production. Since an irrigation system is a large expense for a cranberry grower, the use of a certified irrigation designer is common and highly recommended.

Nozzle Replacement

When growers were asked if they replaced their sprinkler nozzles, Field 5 nozzles were changed approximately 6 years ago. Field 10 changes sprinkler nozzles every 2 years. Fields 3a, 8 and 12 were 2 years or less in age. If these three fields are removed from consideration, then 2 out of 11 or 18% of farms surveyed have replaced nozzles. Best management practices suggest replacing nozzles every 2-3 years under normal operating conditions (8).

Nozzle Orifice Wear

Lampinen , B. et al. (1) noted that a 1/64 in. expansion in nozzle orifice will increase water use by approximately 1 gallon (3.75 L) per minute.
Nozzle orifice wear was performed early on in the survey on two fields using the drill bit test. However, the author found it challenging to judge nozzle wear objectively with this test. Protocol suggests if the drill bit shank inserted into the nozzle orifice can be moved 5-10^0 from center, the nozzle should be considered for replacement. Measuring 5^0 or less and between 5-10^0 was difficult to determine accurately and therefore subjective. Consequently, the drill bit test was abandoned for the remainder of the survey.

Tail Water Recovery

Growers were asked if their field (farm) was designed to recover field drainage water (tail water). Twelve out of fourteen fields or 86% of fields assessed were designed to recover tail water. Storage capability of reservoirs was not assessed.

Nozzle Pressure Measurements

Nozzle pressure measurements were performed on sprinkler heads close to the pump and furthest (far) from the pump while conducting uniformity catch can testing. Ten nozzle pressure measurements were made in the vicinity of the catch cans, but not on nozzles directly discharging over the catch cans. The average of these measurements was calculated and appear in Table 3.

Field #	Pump Operating Pressure (psi)	AVE Nozzle Pressure CLOSE (psi)	AVE Nozzle Pressure FAR (psi)	DEV. CLOSE vs. FAR (psi)	Pressure Loss Across System	AVE Nozzle Pressure (psi)
1	63	61.5	55.6	5.9	9.59%	58.6
2	64	56.0	52.8	3.2	5.71%	54.4
3	54	47.0	34.8	12.2	25.96%	40.9
3a	58	49.7	45.0	4.70	9.46%	47.3
4	50	42.0	41.0	1.0	2.38%	41.5
4a	48	40	36.3	3.7	9.25%	38.2
5	62	54	63.8	9.80	18.15%	58.9
6	54	51.8	41.9	9.9	19.11%	46.9
7	47	20.9	19.2	1.7	8.13%	20.1
8	68	64.8	50.0	14.8	22.84%	57.4
9	58	51.2	45.7	5.5	10.74%	48.5
10	60	62.4	63.7	1.3	2.08%	63.1
11	55	49.8	46.0	3.8	7.63%	47.9
12	60	53.5	54.0	0.5	0.93%	53.6

Table 3. Pump operating pressure and average sprinkler pressures of survey fields
Red indicates pressure losses across irrigation system exceeding 15% maximum recommended

Nozzle pressure measurements are a relatively quick test and can reveal several issues within an irrigation system. Plugged sprinkler nozzles are readily evident upon observation, but leaks in saddles or laterals can be verified quickly. While checking nozzle pressures in Field 3, a broken T was discovered at the end of one lateral which measured an 18 psi drop in nozzle pressure on the broken T compared to surrounding nozzles.

Measuring nozzle pressures on rotator heads found in Fields 3a and 11 was challenging. The rotator head continues to turn, as does the internal diffuser, effectively creating more “blow-by” of the water stream compared to impact nozzle heads. In addition to soaking the person attempting to measure the nozzle pressure, pressure measurements could be inaccurate by several psi. There are flush tools available for the Nelson R33 and R2000 rotator sprinkler heads, but they were not available to the researcher at time of assessment. A more accurate measurement of rotator head sprinkler nozzle pressures would involve removing the cap of the sprinkler head with the appropriate removal tool and measuring nozzle stream flow ion the nozzle inside the head.

System operating pressure should fall within the range of 45 to 60 psi, with pressure requirements increasing as system spacing increases (1). Measuring sprinkler nozzle pressures close to and furthest from the pump provides an overall picture of the irrigation system's balance and performance. Some pressure loss is expected across an irrigation system due to friction and head loss. However, pressure losses across an entire irrigation system should be limited to <15% of pressure at the first sprinkler off the main water line (1). Fields 3, 5, 6 and 8 showed average pressure variations across the system of 25.96%, 18.15%, 19.11% and 22.84%, respectively. Such large variations suggest leaks in the main or lateral lines or possibly inadequate system design. The fact that Fields 3 and 5, both a collection of smaller fields that were merged into single larger acreages, suggests that irrigation system integration may be a contributing factor to large pressure drops across their respective systems.
Fields 6 and 8 also have large pressure differences across the field, although the Field 6 system is 16 years older than field 8. System age may be a contributing factor in large pressure differences across the field. Field 6 is also a peat field (prone to more lateral movement?) while Field 8 is a mineral soil. Field 8 also had some of the longest lateral lines at 900 ft which could result in large friction losses, even though the sprinklers were operating at an average 50 psi in that area.

Field 7 is a 20+ year old irrigation system with the smallest spacing, 30 x 30 ft., of the survey group. While the drop in pressure across the field was minimal at 8.13%, a significant, 55% drop in pressure from the pump to the closest sprinkler, suggests an issue with the delivery system. Average nozzle pressures across the field were 20.06 psi, well below suggested sprinkler operating pressures. It was also noted that when the pump was operating to irrigate the 6 acre, a total of 12 acres of irrigation was operating at the same time. This practice of irrigating multiple fields at once occurred on several farms.
Field 10 sprinkler nozzle pressures both close to and furthest from the pump were higher than the pump's operating pressure. This can be explained by the pump being located approximately 30 feet (9 m) above the field site, resulting in significant head pressure.

System Uniformity Measurement
The ability to perform uniformity measurements was challenging with the type of spring experienced in 2010. Cool, wet, blustery conditions postponed several uniformity measurements. Conditions should be as calm as possible when doing uniformity tests to measure the systems maximum potential uniformity.

The initial intent of the survey was to measure Distribution Uniformity as outlined by the BC Irrigation System Assessment Guide (7). Distribution uniformity measurement of Field 1 utilized 24 catch cans per plot; all other uniformity assessments utilized 36 cans. This increased the number of catch cans ranked in the lowest quartile from 6 to 9.
Distribution Uniformity and Coefficient of Uniformity of the fields surveyed are presented in Table 4. It was observed that DU% was consistently lower relative to CU% for the same field or measurement. Average CU% ranged from 7% to 29% higher than Average DU%; not surprising since CU% as a calculation considers under-watering and over-watering the same, not emphasizing one factor over the other as DU% does. Of course, the higher the DU% or CU%, the more uniform the system and that is

the goal growers should strive for. However, as per discussion outlined earlier in Materials and Methods, further discussion of irrigation uniformity will focus on CU%.

Field #	AVE DU CLOSE (%)	AVE DU FAR (%)	AVE DU TOTAL (%)	AVE CU CLOSE (%)	AVE CU FAR (%)	AVE CU TOTAL (%)
1	72.8	73.0	72.9	83.3	83.6	83.5
2	69.4	71.5	70.5	81.4	82.6	82.0
3	71.5	53.7	62.6	80.9	68.7	74.8
3a	70.1	67	68.6	79.9	82.3	81.1
4	50.7	54.7	52.7	64.0	68.6	66.3
4a	54.0	62.2	58.1	72.8	68.8	70.8
5	49.7	60.2	54.9	65.9	67.7	66.8
6	31.0	39.5	35.3	48.3	52.0	50.2
7	48.3	42.8	45.6	61.7	55.7	58.7
8	57.5	55.5	56.5	73.3	67.7	70.5
9	61.5	61.6	61.6	70.2	74.9	72.6
10	65.6	54.9	60.3	78.1	69.1	73.6
11	55.0	70.0	62.5	73.4	80.8+	-*
12	65.2	84.0	74.6	75.5	85.0	80.3

Table 4. Distribution Uniformity and Coefficient of Uniformity of survey fields

*two different sprinkler types, impact & rotator, were used in the field; no average calculated;
+ indicates R200 Rotator head

USDA NRCS recommends that for new irrigation systems, CU% should achieve an ideal uniformity of $\geq$ 85% when designing or improving irrigation systems (1, 4). It is also suggested that a CU of <70% indicates that a system needs updating and improvement. Using these criteria, 4 of 14 irrigation systems assessed or 28.6% of the survey group require attention to improve their CU% and 10 of 14 fields surveyed or 71% of irrigation systems met or surpassed the 70% CU threshold.

While Field 6 exhibited the lowest Average CU of the survey at 50%, the CU was also measured on a very windy day. Unfortunately, Field 6 was not reassessed under calmer conditions which should have improved its CU% substantially. In BC, acceptable uniformity coefficients for normal irrigation practices is suggested at 80% CU and if chemigation is practiced, uniformity coefficients of 90% are desired (5, 6). The highest Average CU% were measured on Fields 1,2,3a and 12, all at 80% CU or higher. Fields 1 and 2 had 40 x 50 ft. sprinkler spacing patterns in an H and offset design, respectively. Field 3a had a 55 x 55 ft. offset spacing with rotator sprinkler heads and Field 12 was a < 1 year old irrigation system of 60 x 60 ft. impact sprinkler and offset spacing.

Precipitation Rate

Data collected from an irrigation uniformity test can be used to calculate the system's irrigation or precipitation rate, expressed in inches/hour. In order for frost protection to be effective, an irrigation system should apply water at a minimum rate of 0.1 inch per hour to protect to 24 ^{0} F or -4^{0}C (1). Cranberry irrigation systems are often designed to provide a margin of error of 0.14 in/hr for protection to 21^{0}F or -6^{0}C. Consequently, BC cranberry irrigation rates should fall within these parameters.

FIELD #	CLOSE Precip. Rate (in/hr)	FAR Precip. Rate (in/hr)	AVE Precip. Rate (in/hr)
1	0.1523	0.1475	0.1499
2	0.1472	0.1537	0.1505
3	0.1194	0.1018	0.1106
3a	0.1388	0.1197	0.1293
4	0.1469	0.1229	0.1349
4a	0.1057	0.0962	0.1010
5	0.1774	0.1929	0.1852
6	0.1300	0.1295	0.1210
7	0.0754	0.0728	0.0741
8	0.2221	0.2217	0.2174
9	0.1229	0.1341	0.1285
10	0.1585	0.1307	0.1446
11	0.1314	0.1118	0.1216
12	0.1235	0.1204	0.1220

Table 5. Irrigation system precipitation rates

All of the fields calculated average precipitation rates fall within or slightly above recommended cranberry frost protection precipitation rates with the exception of Fields 7 and 8. The average precipitation rate for Field 7 is 0.0741 in/hr, 26% below recommended frost protection rates. Field 7 also exhibited slow sprinkler head rotation and streaming of the nozzle discharge, both indicators of insufficient operating pressure.

Conversely, Field 8 had an average precipitation rate of 0.2174 in/hr, 55% above the recommended margin of error for frost protection. The field was planted two years ago suggesting nozzle wear is minimal. This system is applying twice the amount of water required for minimum frost protection. Whether the field is being over irrigated depends on the soil type, infiltration rate, drainage and crop use. Modifications in this case could be made by adjusting operating pressure or nozzle size.

Sprinkler nozzle output in a system can also be measured directly using a bucket test. This involves fitting a small length of hose over the nozzle to discharge into a bucket of known volume over a set period of time. This could also be done in the vicinity of catch can grids set up for uniformity measurements. The actual nozzle output is then compared to published/calculated values available from the manufacturer to quantify nozzle wear. If measured nozzle output exceeds published/calculated output by 0.5 gpm the nozzles should be replaced (4). Precipitation rate can also be calculated from data gathered by this method. The bucket test was outside the scope of this survey.

Conclusion

Cranberry irrigation system performance should be evaluated on a regular basis to insure satisfactory performance. Evaluation and awareness of potential nozzle wear is low among the group of cranberry farms surveyed, with 14% of the group having changed nozzles on established systems. The same trend is apparent for assessing irrigation system uniformity, where only 7% of the group surveyed had tested for system uniformity. This suggests growers are relying on irrigation designers to meet coefficient of uniformities in the initial design of systems.

A very encouraging observation of the farms surveyed, was that 86% were designed with tail water recovery. Closed systems increase flexibility in water management options and provide an extra level of protection for the environment.

Nozzle pressure measurements across an irrigation system can provide insight into possible problems affecting irrigation system uniformity and performance.

Irrigation system precipitation rate calculated from catch can uniformity measurement is a useful tool to determine actual irrigation application rate. However, it has limited value when determining nozzle orifice wear. It can reveal whether or not actual application rates are meeting minimum standards for frost protection and crop irrigation, but it is subject to factors influencing uniformity such as lateral and riser spacing, height, stability, sprinkler head maintenance and wind. In addition, the drill bit test is limited in accuracy and at best can suggest that there is some nozzle orifice wear but this is hard to quantify. The bucket test (as described under Precipitation Rate), to confirm nozzle output may be a more accurate indication of nozzle wear.

Irrigation system uniformity testing and evaluation suggests that for cranberry irrigation systems, CU% may be a more appropriate calculation compared to DU%, although both calculations should be as high as possible. The survey indicated that 28% of irrigation systems surveyed require attention in order to increase their CU% and 71% of systems met or surpassed the USDA NRCS minimum CU threshold of 70%. The British Columbia Sprinkler Irrigation Manual (5) suggests an irrigation system normal operating threshold of 80% CU. This was achieved by 38% of the survey group.

Understanding irrigation system design and physical characteristics are important factors to consider when assessing system performance as a whole. The survey indicated a range of sprinkler spacing and uniformities. Consequently, each system must be evaluated based on inherent design characteristics and component adjustments made to maximize uniformity within these design limits. If maximum uniformity of a specific irrigation system falls short of minimum uniformity recommendations following component adjustments, major system redesign may be required.

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