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BREEDING THE AMERICAN CRANBERRY

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Why is a particular cranberry variety grown?

The cranberry varieties that are cultivated, are grown for their particular combinations of characteristics. Obvious desirable traits in cranberry are productivity, color, and fruit quality. As with most crops, productivity is a major criteria for selection a variety to culture. Productivity, however, is a complicated trait with many genetic components, e.g. vine vigor, flowering upright density, adaptation, fruit set, etc. Productivity is also impacted greatly by environment.

In 1958, after over 100 years of commercial cranberry production, 92% of the cranberry acreage was planted with only four varieties: 'Early Black', 'Howes', 'McFarlin' and 'Searles'. These varieties, selected from native bogs, were referred to as the 'Big Four', and were cultivated based regional preferences.

'Searles', the predominant variety grown in Wisconsin, was recognized for it productivity. Dr. H.J. Franklin, was noted as saying that 'Searles' "is perhaps the most productive of all cultivated cranberries". However, 'Searles' was considered to have only poor to fair fruit quality, particularly on the east coast. 'McFarlin', another variety grown in Wisconsin, was also grown widely in the Pacific Northwest. 'McFarlin' was noted for good fruit quality and a berry that was resistant to frost. 'McFarlin' was considered to be as productive as 'Howes', but producing more uniform crops in certain areas. 'Early Black' and 'Howes' were and still are east coast varieties. 'Early Black' was noted for early color and ability to produce on many types of cranberry soil. 'Howes' was noted for very good fruit quality, with a berry very resistant to frost.

Why breed new varieties?

There are two major reasons for breeding new varieties. Through breeding one can enhance levels of certain traits. Obvious traits in cranberry are productivity, disease resistance and TACY. A second reason would to develop varieties with desirable trait combinations. Desirable trait combinations for most cranberry growing regions are high yield, high TACY and resistance to diseases of a given growing region. For Wisconsin, cotton ball and vicid rot resistance combined with enhanced levels of productivity and TACY would be desirable.

The genetic enhancement of cranberry: the first generation of breeding and selection

In 1929, the USDA embarked on cranberry breeding program. A major objective of the program was to develop cranberry varieties resistant to false-blossom disease. This is probably why the varieties 'Early Black' and 'McFarlin' were used as parents. From over 30 crosses, over 10,000 seedlings were planted. The majority (8,692) were planted in NJ and 1,993 seedlings were planted in MA. Six varieties, all initially selected from NJ, were released: 'Stevens', 'Pilgrim', 'Franklin', 'Wilcox', 'Bergman', and 'Beckwith'. Of these, 'Pilgrim', 'Beckwith' and 'Franklin' were considered to have high resistance to false-blossom.

Besides identifying resistant varieties to false-blossom, selection criteria included: yield, fruit rot resistance, keeping quality, fruit appearance, coloring in storage, date of harvest, and fruit size. The program was terminated after one generation of breeding and selection. A replicated variety trial at the Blueberry and Cranberry Research Center, Chatsworth, NJ has shown that the first generation hybrids, as a group, are more productive than wild selections.

Continued breeding

A strong argument for continued breeding of cranberry is the success of the variety 'Stevens'. The variety 'Stevens' represents a successful outcome of a previous cranberry breeding program. 'Stevens' was derived from a 'McFarlin' X 'Potters' hybridization. 'McFarlin', was noted as having good production, good keeping quality, resistance to false-blossom, but late maturing fruit. 'Potters' traits were good production and early ripening, but was considered to have "very poor" keeping quality and susceptible to false-blossom. Although both parents had "good production", 'Stevens' is more productive than either parent. 'Stevens' considered of good keeping quality, probably received this trait from 'McFarlin', and is intermediate to both parents for TACY and resistance to false-blossom. Additional genetic gain should be possible with additional breeding and selection cycles in cranberry.

Additional reasons exist for breeding new varieties. The culture of one or few varieties, a mono-culture of sorts, exposes the industry to higher risk of epidemics. Having diverse varieties planted may provide a buffer to disease or insect outbreaks. Varieties with disease resistance would reduce the use of pesticides. The benefits would not only be environmental. Some pesticides, such as chlorothalonil, have been shown to be phytotoxic to the cranberry. Varieties having greater resistance may allow for lower rates of pesticide to be used. As mentioned later, loss can occur even with the use of pesticides. Varieties having some level of resistance could reduce this loss.

The NJAES/Rutgers University Cranberry Breeding Program

A Perspective on Cranberry Breeding in NJ -

The climate and soils of NJ make an excellent site for the breeding of perennials. Varieties of blueberry, peach, apple, and turfgrasses selected in NJ are widely grown in North America. The southern coastal plain of New Jersey offers an ideal site to select broadly adapted cranberry varieties. The six varieties, including 'Stevens', released from the 1929 USDA breeding program were initially set out and selected at Whitesbog, NJ.

The southern coastal plain of NJ is the most southern range of the main distribution of native cranberry. Cranberry is best adapted to cool temperate summer climates. The summer heat and humidity of the southern coastal plain of New Jersey provides a severe test for adaptation to adverse conditions: heat stress and high disease pressure. As a result of the hot humid summer climate, NJ cranberry bogs are likely subjected to the greatest field fruit rot disease pressure of any of the cranberry growing regions.

In NJ, cranberry plantings are regularly sprayed with fungicides with up to four applications; even with four fungicide applications, some plots can suffer 10-15% loss due to fruit rot organisms. Unsprayed 'Benlear' plots at the Center have exhibited 100% rotted fruit in some years. Over 15 different pathogens have been determined to cause fruit rot in NJ. The major organisms, in approximate order of importance, are: Blotch rot (*Physalospora vaccinii*), Bitter rot

(*Glomerella cingulata*), Ripe rot (*Coleophoma empetri*), Early rot or scald (*Phylosticta vaccinii*), Botryospheria (*Botryospheria vaccinii*). In some years, End rot (*Godronia cassandrae*) and *Alternaria* are also a problem.

The NJAES Cranberry Breeding Program: Objectives, Approach and Time-frame

Based on the needs of the industry, the major objectives of breeding program are: 1) reliable productivity and 2) resistance to fruit rot organisms. Other characteristics such as TACY, brix, acids are also being evaluated. However, the pressure to reduce use of pesticides makes resistance of highest priority.

The primary effort will involve breeding, controlled crosses, and selection. Since both of the major objectives have a large environmental component, field plots are being established along with replicated field trials to obtain better estimates of the genetic and environmental components. Even in a bog of a relatively homogeneous variety, e.g. 'Stevens', there can be considerable variability for productivity and fruit rot. Thus, when a bog is planted with many plots of different genetic constitutions, the design should be such as to increase the probability of selecting the superior seedling resulting from a superior genetic constitution, and not as a result of a favorable environmental situation.

The evaluation of the germplasm and seedlings will identify useful genotypes (genetic variation) for parental material. Parents will be selected and controlled crosses made to generate progeny with enhanced traits and trait combinations. The most efficient genetic gain is achieved by obtaining an accurate estimate of the genetic component; for traits like yield, this can only be achieved through field testing and good experimental design.

In cranberry breeding, the time interval from cross to release is substantial. In the USDA program crosses were made in 1929 and the first releases were in 1950, 21 years. With replicated field trials, this time interval could be shortened to 12-15 years.

Cranberry Germplasm and Evaluation

Breeding programs require genetic variation. A major effort has been made to assemble cranberry germplasm, both selected and wild at the Center. Over 500 accessions and varieties are being maintained in either greenhouse and/or field plots. Clonal collections from native bogs have also been made. States from which plants of native populations have been obtained include: DE, MA, MI, NC, NJ, NY, PA, and WI. Field plots of all the accessions are planned for evaluation. Field plots will be evaluated for yield, fruit rot, color, vigor, etc.

To obtain a better understanding of the diversity and genetic variation of the cranberry germplasm, biochemical and DNA fingerprinting studies have been and are being conducted. These will be useful in identifying unique plants and understanding the genetic relatedness of plants.

Disease Resistance

The development of productive varieties with resistance to the fruit rot organisms requires the identification of resistant varieties. The identification of resistance will utilize two approaches. One will involve testing for field resistance. Field plots will be set out and fungicide sprays will be reduced or eliminated. The other will involve an artificial screening in laboratory or greenhouse

through controlled inoculation. Artificial screening will be done in cooperation with the plant pathologist, Dr. Peter Oudemans, at the Center.

A number of the varieties considered to have some level of fruit rot resistance have been crossed with productive varieties, and seedlings have been field planted.

Yield and Yield Evaluation

The cranberry varieties being grown today have been selected for cultivation based largely on grower experience. Few replicated trials have been conducted to determine superior varieties for a given region. As a result, the acceptance of new varieties is slowed. For example, 'Stevens' was released in 1950, but only relatively recently is it being widely planted. Although costly of time and space, replicated field trials are the most efficient and quickest method of identifying productive varieties. Due to the phenomenon of 'biennial bearing' in woody perennials, tests running few to many years are required to assess yield potential.

Current Status and Outlook

A replicated cranberry variety trial was established in 1985. The trial has 10 varieties planted in a replicated, 4 replicates, design. Traits being measured include yield, components of yield, and fruit rot. Fairly complete data is available for years 1991, 1992, and 1993. One objective of this trial is to determine the best design for future trials with selections from the breeding program.

Over 150 controlled hybridizations have been made. Over 3,600 seedlings have been field planted either at the Center or cooperating growers locations. An additional 2,000 seedlings will be planted in Spring 1994.

If the success that has been made in other fruit crops through breeding is any indication, future generations of cranberry should provide the industry with superior varieties to those currently grown.

CRANBERRY CULTIVAR EVALUATION

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A total of 93 cranberry varieties or cultivars, has been collected and is being maintained at plots at the DuBay Cranberry Company Marsh. Twenty cultivars are being maintained in plots at the Jacob Searles Marsh. In addition, 25 cultivars grown from seed of open-pollinated flowers of the Ben Lear variety are in plots at the Dubay marsh and over 600 seedlings from crosses made by Dr. Nicholas Vorsa of the New Jersey Experimental Station have also been planted at the DuBay marsh.

This report is on the 69 selected cultivars all growing in one bed at the DuBay marsh. Data have been taken on these cultivars over the last 16 years, but the years 1983-1992 are included here, since the data are most complete for those years. Data for the 1993 season are being prepared for a report to the Wisconsin Cranberry Board, Inc.

Data on yield were obtained by hand picking the berries from two one-square-foot areas in each variety plot, weighing the berries and calculating the yield per acre. Berry weight data were obtained by weighing a two quart sample of berries, counting the berries in the sample and calculating the weight per berry. Berries per cup were also counted for several years. Storage rot was determined by sorting berries of a two-quart sample, counting and classifying the rotted, breakdown, or sound berries per sample. The berries had been held in refrigerated storage for approximately four months. The Ocean Spray Company laboratory at Babcock, Wisconsin made the berry color determination.

Most of the highest yielding cultivars are little known in Wisconsin. The top ten were WSU 108, DF5, Centerville, AJ, F.N. Searles, AR2, Thunder Lake 3, HA, Wilcox and Bain Favorite #1. Other characteristics of these varieties need to be considered in evaluating them for planting. Highest color readings were obtained for Early Black, Franklin, Ben Lear, AA4, Bergman, Bain 6, BE4, Bain 3, Crowley and Middleboro. The largest berries were produced by Bain favorite #1, Bain 10, Habelman 2, Pilgrim, Bain 8, Bain 11, Stevens, Hollister Red, Stankovich and Thunder Lake 3. Poorest keepers in storage were Prolific, Matthews, Habelman 2, Norman Le Munyon, 41, Hollistar Red, Paradise Meadow, Drever, Stankovich and Pilgrim. The best keepers were Howes, Centerville, BE4, Early Black, Early Richard, 35, Bain 11, Rezin McFarlin, WSU 77, Bain 5 and AA4.

Berry samples will be on hand at the March 16 Cranberry School for examination and further evaluation.

The support of this work by the DuBay Cranberry Co., Jacob Searles Cranberry Co., Ocean Spray Cranberries, Inc. and the Wisconsin Cranberry Growers Association, through the Wisconsin Cranberry Board, Inc., is greatly appreciated. Special thanks are extended to Harold Mezera for help in the plot work and to Jayne Sojka for help in collecting and collating the data.

Multi-year Summary of Evaluation Data of Cranberry Cultivars in DuBay Marsh Plots[1]

Cultivar	Yield	Color	Berry size	Percent Storage Rot	
	Bbls/A	TAcy	gm	Dry Raked	Wet Raked
AA4	235.0	57.1	1.03	3.3	7.7
AJ	305.8	40.2	1.18	4.3	13.8
AR2	298.6	20.0	1.42	3.3	10.0
AW2	227.9	44.6	1.04	5.0	12.3
Bain 1	216.2[2]	42.7	1.51	6.5	8.7
Bain 2	256.3	36.6	1.15	4.3	10.1
Bain 3	212.5	46.6	1.32	5.5	13.8
Bain 4	279.3	40.3	1.24	3.2	10.8
Bain 5	203.5	42.5	1.15	3.8	7.7
Bain 6	235.2	50.5	1.40	4.4	12.3
Bain 7	280.7	42.8	1.33	6.6	12.7
Bain 8	259.6	35.2	1.56	6.3	14.0
Bain 9	252.9	33.0	1.48	4.4	11.3
Bain 10	271.3	32.9	1.65	5.2	10.5
Bain 11	276.8	29.6	1.53	5.8	6.8
Bain Favorite #1	284.6	17.3	1.72	4.2	11.9
Bain Favorite #2	269.4	24.7	1.44	2.9	8.3
Bain McFarlin	222.3	31.6	1.35	4.2	7.9
BD	275.6	43.8	1.06	4.3	10.7
BE4	284.0	48.2	1.14	2.7	4.6
Beckwith	281.2	32.5	1.43	4.8	11.5
Ben Lear	241.7	60.5	1.36	6.6	16.8
Bergman	253.5	53.1	1.29	5.9	10.3
Biron Selection	203.0	33.6	1.51	5.4	10.9
Centennial	275.9	34.7	1.43	4.8	8.7
Centerville	309.0[2]	30.1	1.08	3.9	4.2

Cultivar	Yield	Color	Berry	Percent Storage Rot	
	Bbls/A	TAcy	size gm	Dry Raked	Wet Raked
CN	282.6	33.6	1.34	4.6	14.6
Cropper	261.8	39.2	1.32	6.0	8.5
Crowley	277.6	46.1	1.48	6.3	11.3
DF5	315.7	39.9	1.32	6.2	17.3
Drever	259.5	33.3	1.43	7.9	18.7
Early Black	220.2	65.1	0.81	4.0	4.8
Early Richard	181.7[2]	40.1	1.11	3.3	5.8
Eastern Variety	269.0	24.9	1.21	3.3	8.6
FN Searles	301.6[2]	27.9	1.47	6.0	11.7
Franklin	210.6	61.2	1.05	4.7	10.7
Foxboro Howes	195.2[2]	29.0	0.91	2.3	--
Gebhardt Beauty	280.7	25.3	1.48	4.1	12.1
HA	291.0	34.7	1.41	6.5	12.1
Habelman	230.6	35.4	1.11	4.1	8.3
Habelman #2	243.6[2]	39.5	1.64	9.3	12.1
Holliston	241.9	35.8	1.34	6.2	18.3
Hollistar Red	261.2	29.6	1.51	8.6	15.6
Howes	233.5	28.7	0.91	2.1	3.8
Matthews	246.4	34.7	1.40	9.5	15.4
Middleboro	149.3[2]	46.0	1.05	3.0	--
New Jersey 10	266.3	40.6	1.13	4.3	8.5
Norman Le Munyon	200.6	34.3	1.30	9.1	13.4
Paradise Meadow	212.9[2]	32.4	1.03	8.3	--
Pilgrim	250.9	38.6	1.61	7.1	26.3
Prolific	276.6	28.4	1.33	11.7	25.3
Rezin	242.2	44.5	1.09	3.7	12.7
Rezin McFarlin	219.0	28.1	1.25	2.5	7.2

Cultivar	Yield	Color	Berry size	Percent Storage Rot	
	Bbls/A	TAcy	gm	Dry Raked	Wet Raked
Round Howes	202.0[2]	27.1	0.88	1.8	--
Searles	257.2	28.9	1.36	3.8	13.9
Stankovich	247.2	39.1	1.51	7.7	21.2
Stanley	151.0[2]	40.6	1.01	4.6	--
Stevens	268.9	31.8	1.52	4.0	9.0
Thunder Lake 3	292.6[2]	38.6	1.51	4.8	15.4
Thunder Lake 4	247.7[2]	35.6	1.50	3.9	9.0
Wales Henry	204.2[2]	27.5	1.04	6.8	--
Wilcox	289.8[2]	30.0	1.00	2.9	8.1
WSU 61	242.7	44.3	1.25	4.4	12.0
WSU 77	255.7	23.0	1.34	3.7	7.3
WSU 108	319.7	32.4	1.20	6.9	15.1
6	241.3	41.1	1.13	3.1	9.6
20	261.3	26.6	1.30	4.8	11.8
35	253.8	26.4	1.34	3.0	6.4
41	240.9	33.2	1.32	9.0	14.1

[1] Yield, color and berry size data are for the ten year period 1983-1992, with some exceptions where data for some years were lacking for certain cultivars. Storage rot data for dry raked berries are for the eight years 1985-1992, that for the wet raked berries are for the three years 1989, 1991 and 1992. Storage rot data were taken after four months of refrigerated storage.

[2] Yield data for the cultivars indicated are for only five to seven years.

VINES VERSUS TRANSPLANTS FOR PLANTING IN YOUR MARSH

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Traditionally, cranberry beds have been established by utilizing vines that have been harvested from well-established beds. Such practices continue to work very well for there are a number of distinct advantages for this approach:

- The vines are harvested dormant and thus can be stored for extended periods in unsophisticated storages until planting can be accomplished in early spring.
- Planting of vines does not require expensive sophisticated equipment or specially-trained personnel.
- The planting density is relatively dense, thus it is not essential (although it certainly is desirable) for a very high percentage of the individual vine pieces to 'take' and survive.

However, during the last decade there has been increasing interest in investigating other sources of cranberry propagules as some of the disadvantages of utilizing vines has become apparent:

- A considerable number of years is needed to scale-up production of new cultivars or introductions to the point where large beds are available for harvest of the vines.
- There is little way to certify that the vines harvested off of older beds in fact only consist of the stated cranberry selection. Over the years, confusion as to identification of the original planting stock coupled with the very real possibility of contamination by seedlings and mutants has led to the present situation of numerous different subclones of a particular cultivar being grown, but all identified under the same name. Taking plant material from established beds also moves with it other organisms (such as pests, weeds, and diseases) that are present in that bed. This very concern a major reason why most all other major clonally propagated crops (especially other fruits and vegetables) have strong restrictions against propagating and distributing materials of unknown quality. Cranberries are unique in that they can be transported across most state boundaries with only minimal assurances of freedom from other contaminants.
- Planting is limited to spring. If weather conditions are poor for vine survival during or immediately after planting, a poor plant stand in the field results. This poor stand then leads to delayed fruit production and increased problems with weed pests.

The leading alternative propagation method to vines is the use of transplants generated from cuttings. With this approach, cuttings are multiplied, rooted and established in containers under greenhouse or shadehouse conditions and these plants, usually in active growth, are transplanted to the cranberry bed. Interest in the use of transplants has

stemmed from a number of the advantages associated with the use of this type of propagule:

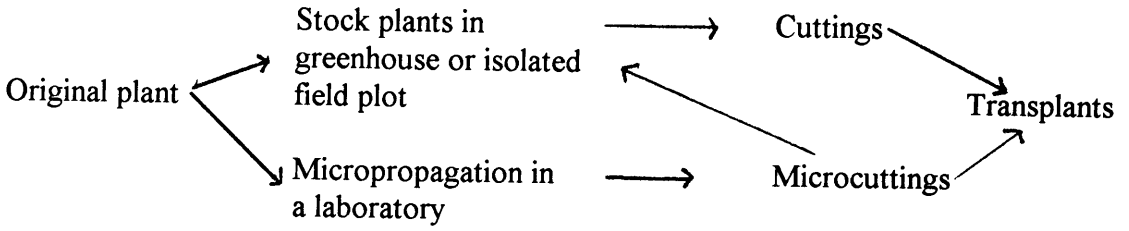
- Rapid scale-up of selections that are not widely available from vines harvested from previously planted beds is very feasible. One plant can be scaled-up to millions within a year's time.
- Transplants can be successfully planted at most any time of the year as long as irrigation is available.
- Transplant technologies can be readily integrated with established practices, including providing plants to fill-in voids in newly planted beds and in renovated parts of established beds.
- Transplants generally show a very rapid establishment of newly planted areas due to a more vigorous and aggressive vegetative (runner) growth during the year of the planting than is normally seen with vines.

There are, however, also a number of complications associated with the use of transplants:

- The use of transplanting machinery ('transplanters'), the most efficient way to plant transplants, is not generally familiar to cranberry growers nor are these machines commonly available in cranberry growing regions. Transplanters are commonly used in the vegetable (e.g. tomatoes), small fruit (e.g. strawberry, blueberry), tobacco, and forestry industries and some of these same units are appropriate for use in cranberry beds.
- Transplants are usually in active growth at the time of planting, thus they need more care both before and after planting than the dormant vines normally used in the cranberry industry.
- Cranberry transplants are not commonly available from commercial propagators. Since there has been little to no demand for cranberry transplants, propagators are not accustomed to working with this crop nor do they have stockplants from which to propagate or inventory from which to fill orders. Thus a grower interested in cranberry transplants must spend considerable time searching out a source and unless the propagator is approached well ahead of planting season, most demands cannot be met.
- Even if a propagation source for cranberry transplants can be found, the price of the transplants may be quite inflated when compared to transplants of other crops. This is due in part to the nature of the cranberry order which will be considered a special order by the propagation firm which has not previously dealt with this plant nor this industry. Most first-time orders will be small (under 100,000 units) and thus propagation efficiencies are low. In addition, cranberry beds are not replanted on any regular cycle, thus the propagation firm has no assurance of return business; scaling-up cranberry propagation for the first year will entail all the normal hassles of working with a new crop for the first time without any assurance that this acquired experience can be used in future years.

With the complications of working with professional propagators cited above, some growers in the East are producing their own transplants.

Cranberry transplants may be generated by any of a number of technologies that are standardly utilized in other industries:



If one is going to go to all the expense and bother of producing and/or utilizing transplants, then they should be *very choosy* about the source of stock from which all the rest of the cuttings will be generated. In particular, the grower should be assured of a number of quality factors:

- The plants must have a high likelihood of being the genetic selection that is wanted. This is no easy task as there is no standard certification program for cranberries that would monitor or even supply standard starting materials which have been screened for their genetic trueness-to-type. At present, probably the best assurance is that the original stock originated from a bed of known productivity and fruit quality. Ideally, propagules from this stock have been grown-on in cranberry beds and shown stability in these characteristics.
- If transplants are purchased, they should be well-established in the soil plug and definitely hardened-off to outdoor conditions.
- No diseases (especially root rots) or pests should be tolerated.

Another major way of assuring that top quality propagules will be obtained is to deal with an established, reputable, experienced professional propagator, ideally one that standardly sells woody, perennial transplants. Not only will this allow a background check through referenced growers of that firm's products, but such propagators usually are very concerned about the performance of their propagules and thus they can be relied upon for advice during the planting and early growth stages.

How many plants will you need? We have found that the maximum spacing is probably 18 inches between transplants. Plants spaced on 12 inch centers will give unbelievable cover the first year in any 'normal' growing season and may even yield a harvestable crop the second year. Closer spacing than 12 inches is too expensive to consider feasible except under unusual circumstances.

Cranberry transplants that have been ordered from a propagator should be planted as soon as possible upon receipt. Since the plants are in soil, they can be kept healthy by just watering, however this requires constant attention; once the transplants thoroughly dry-out, major losses will occur. The transplants will most likely be very vegetative and will

respond dramatically to a constant level of fertilization. After planting, they should be watered-in very well, adequately watered until established in the field, and fertilized heavily the first year.

As new selections begin to emerge from the active breeding and genetic improvement programs, some of which you will hear about at this meeting, you will undoubtedly be faced with deciding if you will use transplants. It may even come to pass that many of the newer cultivars will be distributed through a more tightly controlled program where some aspects of quality can be assured. In any case, please feel free to contact either Eric or myself if we can be of any assistance in helping you balance the trade-offs.

DNA "FINGERPRINTING" of CRANBERRY VARIETIES USING RAPDs

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The majority of cultivated cranberry varieties were selected from native populations in the 1800's and early 1900's from sites primarily in Massachusetts, New Jersey, and Wisconsin. Since their initial selection 100-150 years ago, varietal identities have become increasingly confused. This is primarily the result of a lack of well defined traits, not influenced by environment, that one can use to distinguish one variety from another.

In biology, there has been rapid progress in the development of various molecular markers that can be used to distinguish two individuals from one another. Molecular markers are also used to assess genetic diversity, relatedness and population genetic structure. There are a number of types of molecular markers that are available. They include biochemical (isozymes) and more recently, DNA markers. We have employed DNA markers based on the polymerase chain reaction, referred to as random amplified polymorphic DNA's or RAPD's. This procedure generates DNA band patterns which can uniquely identify or "fingerprint" a variety.

A 22 Cultivar Study

In an initial study, 22 cranberry cultivars originating from MA, WI, and NJ were analyzed utilizing RAPD's. Of the 22 cultivars, only 17 unique genotypes were identified. Three varietal groups had identical DNA fingerprints--1) 'Early Red', 'Howes' and 'McFarlin', 2) 'Biron' and 'Early Richard', and 3) 'Matthews', 'Habelman 2', and 'Norman LeMunyon'. The identification of varieties with identical DNA fingerprints might lead to the conclusion that several different varieties may be represented by an identical fingerprint. However, based on the distribution of number of band differences between pairs of varieties, we have concluded that in this study varieties with the same fingerprint are essentially genetically equivalent, and that one (or more) of the group has been misclassified.

We have also identified varieties having several DNA fingerprints, leading to the conclusion that a variety may be represented by several different genetic variants. Further RAPD analyses were undertaken with the 'Big Four' cultivars: 'McFarlin', 'Howes', 'Early Black', and 'Searles'.

Early Black

Eight clonal samples of 'Early Black' obtained from NJ, WI, and MA were DNA fingerprinted. Four clones (3 from NJ and 1 from WI) had identical fingerprints and were felt to most likely represent a "True" or "Typical" 'Early Black'. This "concensus" fingerprint differed

from the fingerprints of the four remaining clones. These four clones did not appear to be even closely related to a "Typical" 'Early Black', in fact one had a fingerprint identical to two 'McFarlin' clones from the Northwest. In summary, eight 'Early Black' clones generated five DNA fingerprints.

Howes

Seven 'Howes' sampled from NJ, WI, and MA generated five unique DNA fingerprints. A concensus fingerprint for 'Howes' was identified based upon identical fingerprints for three clones from WI, MA, and NJ, respectively. A "sterile" 'Howes' from MA was closely related to the "Typical" 'Howes", whereas the remaining clones appeared to be unrelated. The 'McFarlin'-'Howes'-'Early Red' fingerprint from the 22 cultivar study was found to be that of 'Howes'. The 'McFarlin' and 'Early Red' clones used in the study were evidently 'Howes' that had been misclassified.

Searles

Two 'Searles' from WI were found to be unrelated based upon their DNA fingerprints. A "Flat" 'Searles' appeared to be most closely related to the "Typical" 'Howes'. An additional three 'Searles', also have given unique fingerprints. Five clones of 'Searles' have generated five unique fingerprints; at this time, no concensus fingerprint has been identified for 'Searles'.

McFarlin

The RAPD analyses of six 'McFarlins' were inconclusive with respect to the identification of a concensus fingerprint for this variety. A larger survey of sixty-eight 'McFarlins' obtained from WA, MA, WI, OR,and NJ identified 17 DNA fingerprints for this variety. Twenty-five or 37% of the clones examined were represented by a fingerprint which appears to represent a "Typical" 'McFarlin'. The 'Rezin' and 'Bain' 'McFarlin' have the "Typical" 'McFarlin fingerprint. A group of four clones from a bog in MA and a WA clone appear to be closely related but not identical to the "Typical" group, whereas the remaining 'McFarlins' are clearly unrelated. Nine 'McFarlin' clones, obtained primarily from WA state, appear to be the variety 'Howes', based upon DNA fingerprints.

Conclusions

RAPD technology has shown that a cranberry variety may be represented by several genetic variants. Some variants appear to be the result of varietal misclassification, whereas the remainder are thought to be examples of volunteer seedlings that have become established in a varietal bog. These genetic variants can confound cranberry research studies, and can also seriously impact growers who may unknowingly establish cranberry bogs with less productive variants of a cultivar.

TAKING A PROPER TISSUE SAMPLE FOR MINERAL ANALYSIS

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Tissue analysis is a powerful tool in assessing the mineral nutrition status of crops. Chemically analyzing the concentration of nutrients in the leaves of growing crops can more precisely define the nutrient status than an examination of deficiency symptoms or soil testing alone. This method is based on collecting samples of tissues in the field and measuring the amounts of mineral elements in the tissue. Tissue analysis provides a "snapshot" picture of the nutrient status of a crop at a particular point in time resulting from all factors that affect plant growth and nutrient uptake. In addition to confirming suspected deficiencies, plant analysis can also detect toxicities or hidden deficiencies before visual symptoms appear. Experimentation has shown the amounts of the various minerals that should be present in plants to provide optimal growth. These amounts are shown in Table 1.

The most important part of tissue analysis is taking a proper sample. You must consider three factors when collecting samples:

1. sample the correct plant part,
2. sample at the correct time,
3. collect a sample that is representative of the bed.

What to collect.

The proper plant part to sample for tissue analysis in cranberry is new upright growth. If you collect both current season growth and one-year-old growth your samples may show a deficiency since nutrient levels tend to be lower in one-year-old growth.. The age of tissue can have a profound effect on the results obtained and on the interpretation of the results. You need to exercise caution in collecting samples and it may be prudent to examine samples collected by consultants or others who may be collecting samples for tissue analysis so the results can be interpreted accurately.

When to collect.

In order to make comparisons to standards set by University research it is necessary to collect samples at the correct time of the year. The concentrations of mineral elements in plants changes over time. We recommend taking samples during August each year. At this time the concentration of most elements is stable. If you take a sample in late spring the concentrations of the various elements may be changing rapidly. In this case the date you collect a sample may have more influence than the actual tissue concentration.

One exception to this rule is when samples are collected in early spring before bud break. If the tops of uprights are collected at this time the same tissue will be sampled as if you took the sample in August of the previous year. However, I still recommend August sampling and cautious interpretation of early spring samples.

How to collect.

Only a few handfuls of uprights are taken as samples for tissue analysis. At the laboratory only about of teaspoon of dried and ground tissue is actually analyzed. The sample must be representative of the entire bed. Don't take samples only from one corner or along one edge of a bed. It is best to start in one corner and walk to the opposite corner collecting 4 or 5 samples along the way. Alternatively, you could walk in a zigzag pattern across a bed. Try to sample uprights that represent the bed. The uprights you collect should look like the remaining uprights in the bed. Don't sample overly vigorous or sickly vines. If you are sampling for a particular problem, also collect normal vines for comparison.

Once the tissue sample has been collected it should be prepared for shipment or delivery to the lab. Any soil or foreign material should be dusted off the sample. DO NOT WASH the uprights as this will remove soluble nutrients and will give a false analysis. Place the sample in a small paper bag or paper envelope. If the sample is to be mailed, allow the sample to air dry for one day to prevent mold from forming during shipment. Place the dry sample in a paper envelope for shipping. Do not use plastic or cellophane bags since these retain moisture and promote molding. Try to ship samples early in the week (Wednesday at the latest) to avoid samples deteriorating in warm post offices over the weekend. Plant samples that are delivered to the lab do not need to be air dried if they are delivered within a day after sampling. Please submit an information sheet with each sample describing the crop type, date sampled, and other information necessary to make the best interpretation of the lab results. Plant analysis information sheets are available from the laboratory or your County Extension office.

Conclusions

Plant tissue analysis is a powerful tool that can be used in concert with visual symptoms and soil sampling to measure the effectiveness of your fertilzer program and to monitor for mineral deficiencies. However, the results you get are no better than the sample you submit. Taking an appropriate sample and preparing it properly for delivery to the lab will assure correct results.

Table 1. Proposed concentrations of cranberry tissue samples for determining the nutritional status of cranberry.

	MACRONUTRIENTS		
	Low	Sufficient	High
	----------%		
Nitrogen	<0.90	0.90 to 1.00	>1.00
Phosphorus	<0.13	0.13 to 0.18	>0.19
Potassium	<0.50	0.50 to 0.90	>0.91
Calcium	<0.30	0.31 to 0.60	>0.60
Magnesium	<0.15	0.15 to 0.20	>0.20
Sulfur	<0.07	0.08 to 0.20	>0.20
	MICRONUTRIENTS		
	----------ppm----------		
Iron	<40	40-80	>80
Boron	<10	10-20	>20
Copper	<5	6-10	>10
Zinc	<15	15-30	>30
Manganese	<10	10-200	>200

From: Lloyd Peterson, Department of Horticulture, University of Wisconsin-Madison.

NITROGEN FERTILIZER RATE AND TIMING TRIALS IN OREGON

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Nitrogen (N) fertilizer application to cranberries increases growth, tissue N and yield (1,2). Rates producing responses have generally been small (10 to 50 lb/a) compared to rates used on other fruit crops. The low N requirement coupled with a narrow range of N sufficiency and inexpensive N fertilizer creates a situation that lends itself to over fertilization with N. Growers and researchers report decreased yields when this occurs (1).

Most reported N research focuses on N rates, prediction of N sufficiency growth, yield and quality changes produced by the fertilization. Little attention has been given to the time of N application and the impact this has on cranberry growth and yield (3).

Our objectives were to determine appropriate N rate and timing for south coastal Oregon cranberry production. Determination of seasonal N uptake in cranberries was a step in determining appropriate fertilizer timing.

A three year nitrogen rate and timing experiment was initiated in commercial beds of Stevens and Crowley cranberries in south coastal Oregon in 1988. The Stevens' bed was designated N deficient and the Crowley bed N sufficient on the basis of fertilizer history, yield, appearance and a September sample of fruit bearing upright tissue. Nitrogen as ammonium sulfate was applied at 0, 20, 40 and 60 lb/a. The applications were grouped into 5 timings by equally dividing the total fertilizer amount into 3, 4 or 5 doses. These doses were applied at popcorn, hook, fruitset, early bud and late bud growth stages as shown in Table 1.

The popcorn growth stage is a defined as most buds swollen, ready to break. The hook stage is when cranberry pedicels with pink unopened flower blossoms are visible. Fruitset occurs when pea to marble size berries were visible throughout the bed. Flowers are still present under Oregon conditions. Early bud follows fruitset, when new buds begin to show. Late bud is approximately one month before harvest with buds clearly visible for next year's crop.

At harvest, three sections of cranberry bed totaling 1 ft^2 were cut and removed from each 8 ft by 10 ft plot. Berries were removed, counted and weighed.

A second experiment was initiated in the 20 and 40 lb N/a treatments at the Stevens site in 1989. An application of ammonium sulfate, 10.8% ^{15}N (traceable nitrogen), was substituted for commercial fertilizer in 1/6 of the plot area (9 ft^2) at popcorn, hook, fruitset, early bud and late bud. One section received no ^{15}N and was used to determine ^{15}N natural abundance.

At harvest, whole plants were removed, sectioned into new growth, old growth, fruit and roots. Total N and ^{15}N or traceable N were determined. Nitrogen from fertilizer (Nff) was calculated for the plant parts at each time of application.

Table 1. Nitrogen application amounts for each timing at the 20 lb N/a rate. To calculate amounts applied for the 40 lb N/a rate, multiply these values by 2. To calculate amounts applied for the 60 lb N/a rate, multiply these values by 3.

	Timing				
Growth Stage	1	2	3	4	5
	lb N/a				
popcorn	4		5		6.7
hook	4	5	5		6.7
fruit set	4	5	5	6.7	6.7
early bud	4	5	5	6.7	
late bud	4	5		6.7	

Our results dash the hopes of growers expecting a yield response to N fertilization during the year of application. This research shows current season nitrogen fertilization has little if any influence on cranberry yield even at a site diagnosed a N deficient (Stevens). Data in Table 2 show no yield difference at either site or for any N rate in the first year of the N application trial (1988). This aspect of Cranberry growth is similar to other woody perennials. Nutrients are taken up and translocated to fruit buds or other yield determining areas of the plant before in season fertilizer applications are made. Therefore, changes in fertilizer programs and yield claims from fertilizer programs should be made with caution.

Table 2. Cranberry yield as influenced by N fertilizer rate and year at two Oregon sites[1].

		N Rate			
		lb/a			
Site	Year	0	20	40	60
		g/ft^2			
Crowley	1988	126	108[a]	107[a]	110[a]
	1989	137	165[a]	179[a]	164[a]
	1990	85	110[b]	152[a]	141[a]
Stevens	1988	117	122[a]	104[a]	127[a]
	1989	90	174[c]	307[b]	388[a]
	1990	115	201[c]	314[b]	485[a]

[1]yield in g/ft^2 is approximately bbl/a. Within year means followed the same letter are not different $p = 0.05$.

Cranberry growers approach N fertilization with caution and questions. The research project was initiated in an attempt to answer the common questions of "how much N?," "when to apply N?" and "what source of N to use" Source of N will not be addressed here. Nitrogen rate should be determined for each bed or marsh based on cultivar, past yield and yield potential, tissue N, past fertilization, weather effects and pest problems.

An attempt to address time of N application was made with the initial experiment providing N at 5 timings. Yield data from the third year at the Stevens site was inconclusive as shown in Table 3. The only significant impact of nitrogen at this site, even in the third year was from rate. This outcome is not unexpected as the site was initially nitrogen deficient. Any application of N, regardless of application time, increased yield significantly.

Table 3. Cranberry yield for 1990 as affected by N timing[1].

N Timing	Stevens	Crowley
	..... g/ft^2	
1	322[a]	142[a]
2	296[a]	139[a]
3	351[a]	133[a]
4	331[a]	150[a]
5	370[a]	106[b]

[1]yield in gm ft^2 approximately bbl/a. Within cultivar means followed by the same letter are not different p = 0.05.

The use of traceable N assisted in determining when to apply N. Mean and cumulative Nff data for each N timing are presented in Figure 1. Nff means are low (less than 6%) compared to agronomic and fruit crops, specifically other Vaccinium species (4). Highest Nff was found in new growth and fruit when N was applied at or before fruitset. After fruitset very little fertilizer N entered fruit, new growth or roots. In contrast, Nff in old growth was constant for all times of application.

Even though the Nff was small, the data clearly shows current season fertilizer N is predominantly taken up before early bud. If your goal is to increase N or growth in a N deficient situation, early applications should be considered. However, N applied early in the growing season may promote vegetative growth. Little N applied after fruitset is taken up by the crop.

The idea that early N is detrimental to cranberry yield in N sufficient situations is supported by the response of N timing in the Crowley bed in 1990, Table 3. Cranberry yield from timing 5 where all N was applied by fruitset, was significantly lower than any other application timing.

The interaction of N rate and timing at the Crowley site, even though not significant, provides further insight to fertilization of N sufficient cranberries. In figure 2, note the yield increase with N application to the 40 lb/a rate, and the yield decrease with additional N. Secondly, the detrimental effect of early N application is clearly shown by timing 5. Cranberry yield from timing 5 (bottom line in the figure) was lowest at each N rate.

Conversely, delaying any N until fruitset was detrimental at the 40 lb N/a rate but not at the 60 lb N/a rate, shown by timing 4. This was the only treatment to increase yield with the application of 60 lb N/a.

An approach of moderation in N rate and timing was successful as shown by treatment 1. Treatment 1 tended to produce the highest yield at the 40 lb/a N rate.

In conclusion, this research shows more fertilizer N is taken up when ammonium sulfate is applied at or before fruitset compared to after fruitset. This has implications for N fertilization of cranberries:

N deficient cranberries

N is necessary for new upright growth, therefore apply N as crop begins to grow (popcorn stage), through fruitset.

N sufficient cranberries

Early N applications (popcorn) may promote excess vegetative growth. Apply N during fruitset. Multiple applications are recommended. Apply N when berries become "pea to marble size" until end of bloom. Applications after fruitset may be useful for storage of N in old growth but are of little value for providing fertilizer N to other tissues.

Most growers should fertilize according to timing for N sufficient cranberries because beds or marshes receiving regular fertilization are care should be N sufficient. Tissue tests are excellent for determining cranberry N status.

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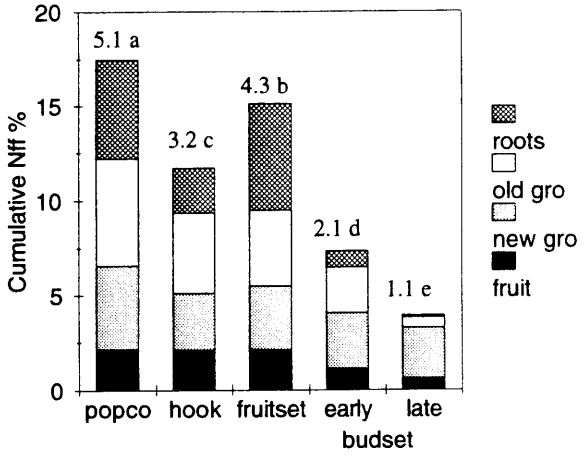

Figure 1. Cranberry tissue N from fertilizer (Nff) of 8 lb ^{15}N/a (40 lb N/a) as influenced by application time. Means followed by the same letter are not significanlty different @ P= 0.05.

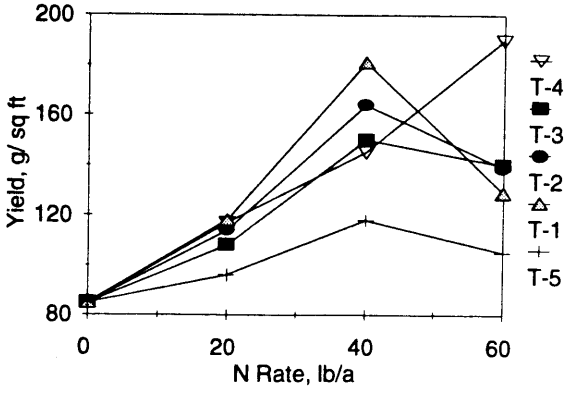

Figure 2. Cranberry yield as influenced by the interaction of N rate and timing at the Crowley site in year 3 (1990).

NITROGEN FERTILIZATION OF CRANBERRIES: WHAT TYPE SHOULD I USE, HOW SHOULD I APPLY IT, AND WHERE IS MY NITROGEN FROM LAST SEASON?

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The potential yield of cranberry plants is closely related to plant nutrition. Of the essential plant nutrients, nitrogen has the greatest impact on plant growth and yield. An adequate supply of nitrogen contributes to proper development, flowering, and productivity of the cranberry plant. Excessive nitrogen uptake will enhance vegetative growth and reduce fruit yield, while inadequate nitrogen uptake will decrease plant vigor and also reduce yield.

Most nitrogen fertilizers are applied as a granular with a boom or as a liquid through irrigation systems. However, some nitrogen is routinely applied as a foliar mist to increase nitrogen content in the upright. Although many research studies have been completed to determine which type of fertilizer may be best suited for cranberries, determining "what" and "how much" the plant is taking up is very difficult. Recently researchers have used an accurate yet expensive technique to determine what type of nitrogen fertilizer the cranberry is utilizing. In an effort to better understand the nitrogen requirements of cranberries, many tests were conducted using this technique. The following results are the most recent and conclusive evidence regarding nitrogen nutrition in cranberries.

SUPPLEMENTAL FOLIAR NITROGEN APPLICATIONS

In previous years many growers have begun using foliar nitrogen products to supplement their existing fertilization program. A series of experiments were conducted on test plots in producing fields to understand the importance of supplemental foliar nitrogen application. In this study, we applied three forms of nitrogen (urea, ammonium, and nitrate) to the cranberry plants every week from early June to mid-July. A total of 3 lb. of nitrogen was applied per acre. The grower applied 40 lb. per acre of granular nitrogen to these plots that season.

Very high percentages of the foliar nitrogen was absorbed by the cranberry shoots (Figure 1). 77% of the Foliar applied urea was recovered in the shoot, and significant levels of both ammonium and nitrate were also absorbed. This study shows that cranberry plants will absorb foliar applied nitrogen at relatively high percentages.

To determine where the absorbed foliar nitrogen was located in the shoot, shoots were separated into uprights, stems, fruit, and leaves (Figure 2). In this seminar, uprights are defined as the current seasons' growth. Stems constitute all old stem material above the soil surface, and leaves are the old leaves from the previous year. Most of the foliar nitrogen was found in equal percentages in both the uprights and stems. Only 8% to 10% of the foliar nitrogen was found in the fruit. This is surprising, because the nitrogen applications were applied during bloom and fruit

set, when supposedly nitrogen was limiting to the fruit. However urea and nitrate fertilizers were in slightly higher concentrations in the uprights than stems, while the majority of ammonium nitrogen was in the stem.

Although up to 77% of the foliar applied nitrogen was recovered by the cranberry plant, the actual quantity of nitrogen absorbed was not very significant (Figure 3). The cranberry plant received 40 lb. of granular nitrogen through the root system. And given the large reserve of nitrogen in the shoot, the 3 lb. of supplemental foliar nitrogen applied to the plant only increased the plants' total nitrogen supply by 3 percent. Some growers feel that a supplemental fertilizer application at bloom and fruit set will improve fruit set and yields. Visually, the foliar nitrogen on cranberries gave the vines a greener appearance than other vines in the bed. Likewise, the upright tissue nitrogen concentration increased from 0.95% to 1.00% because of the foliar fertilizer. However, yields, fruit set, and berry weight were not influenced by supplemental nitrogen applications. The amount of foliar nitrogen found in the fruit was barely detectable, which suggests that use of supplemental nitrogen for increased fruit yields is not true.

FOLIAR AND SOIL APPLIED NITROGEN

Another question asked by growers concerning foliar applications is: Is there a benefit to applying all foliar materials instead of soil applied nitrogen. The answer to this question was addressed. Foliar urea and foliar nitrate fertilizers were supplied to plants at 20 lb. per acre (Foliar applied ammonium fertilizers at this rate would kill cranberry plants). They were compared to soil applied urea, ammonium, or nitrate nitrogen also at 20 lb. per acre. The results are presented on Figure 4. More nitrogen was recovered from foliar fertilizers than soil applied fertilizers. The higher concentration of foliar urea and foliar nitrate resulted in a 58% to 62% recovery. Soil applied nitrogen treatments averaged 40% to 45%, with urea and ammonium performing the best. Surprisingly, it appears that nitrate nitrogen is also absorbed by cranberry plant roots. However, we are not sure if microbes or mycorrhizae are converting the nitrate to ammonium before the plant takes it up, or if cranberries actually use nitrate.

To get nitrogen predominantly to the upright, both foliar applied urea and nitrate worked equally well (Figure 5). Lesser percentages of soil applied nitrogen also were found in the upright. In particular, nitrogen from urea and ammonium were found in greater percentages in the stem. Very little nitrogen was found in the fruit and old leaves.

Figure 6 shows the quantity and location of the foliar applied nitrogen in the shoot. Approximately 33% of the total nitrogen in the uprights and fruit came from the current seasons' nitrogen application. This was typical for the other fertilizers also. The stems, which have many years of nitrogen reserves also received a substantial quantity. These results show that current seasons' nitrogen application only contribute partially to the nitrogen supply needed.

WHERE IS THE NITROGEN FERTILIZER FROM LAST YEAR?

The big question with nitrogen nutrition in a perennial crop is: How much of last year's fertilizers are found in this year's uprights and fruit? Figure 7 shows how much of the original 20 lb. N/acre

was found the first season, then the next season. Overall, 30 to 50 % of last years fertilizer was found in the current season's cranberry shoot. Nitrogen after the second season was located primarily in the stem, probably as storage (Figure 8). Very little nitrogen was found in last year's leaves and fruits. Because so little nitrogen was found in the fruit in consecutive years, the cranberry plant must use previously stored nitrogen forms for its fruit production. The actual quantity of last season's nitrogen found in this season's shoot is depicted in figure 9. Uprights contained only 8% of last season's nitrogen, and the fruit contained significantly less. It is safe to assume that the nitrogen in the uprights and fruit will be detected in small amounts for many years to come.

CONCLUSION

As you learn more about nitrogen fertilizer use from this seminar, it is important to understand that we still do not know everything about the use of nitrate nitrogen by cranberry plants. Some studies conducted in the greenhouse showed that cranberry plants used ammonium fertilizers up to 10 times faster than nitrate. If only nitrate was supplied to the roots, the plant could not absorb it: ammonium had to be there also. Likewise the use of nitrate nitrogen could also raise your soil pH and lead to more serious complications. To date, it is still best to use urea and ammonium fertilizers, but this research shows that nitrate is not a detriment to cranberry production.

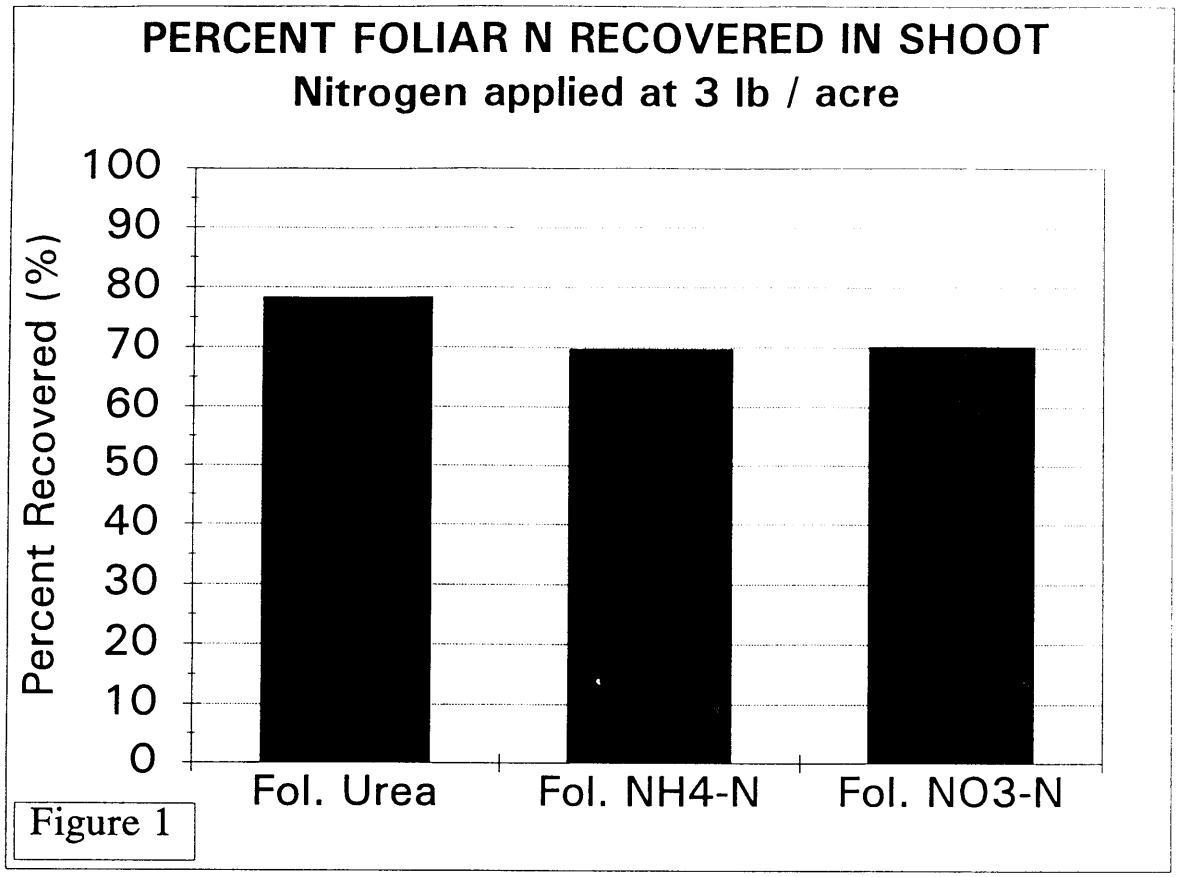

Figure 1

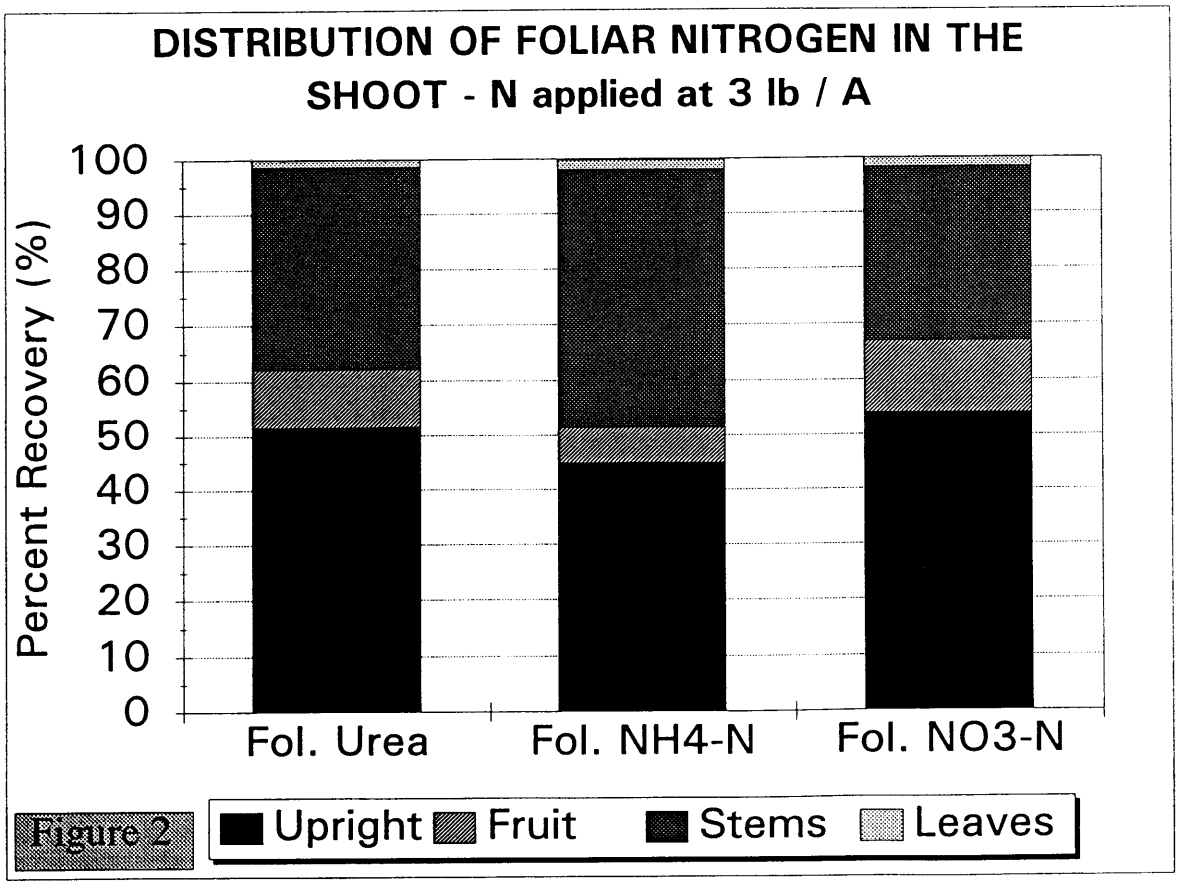

Figure 2

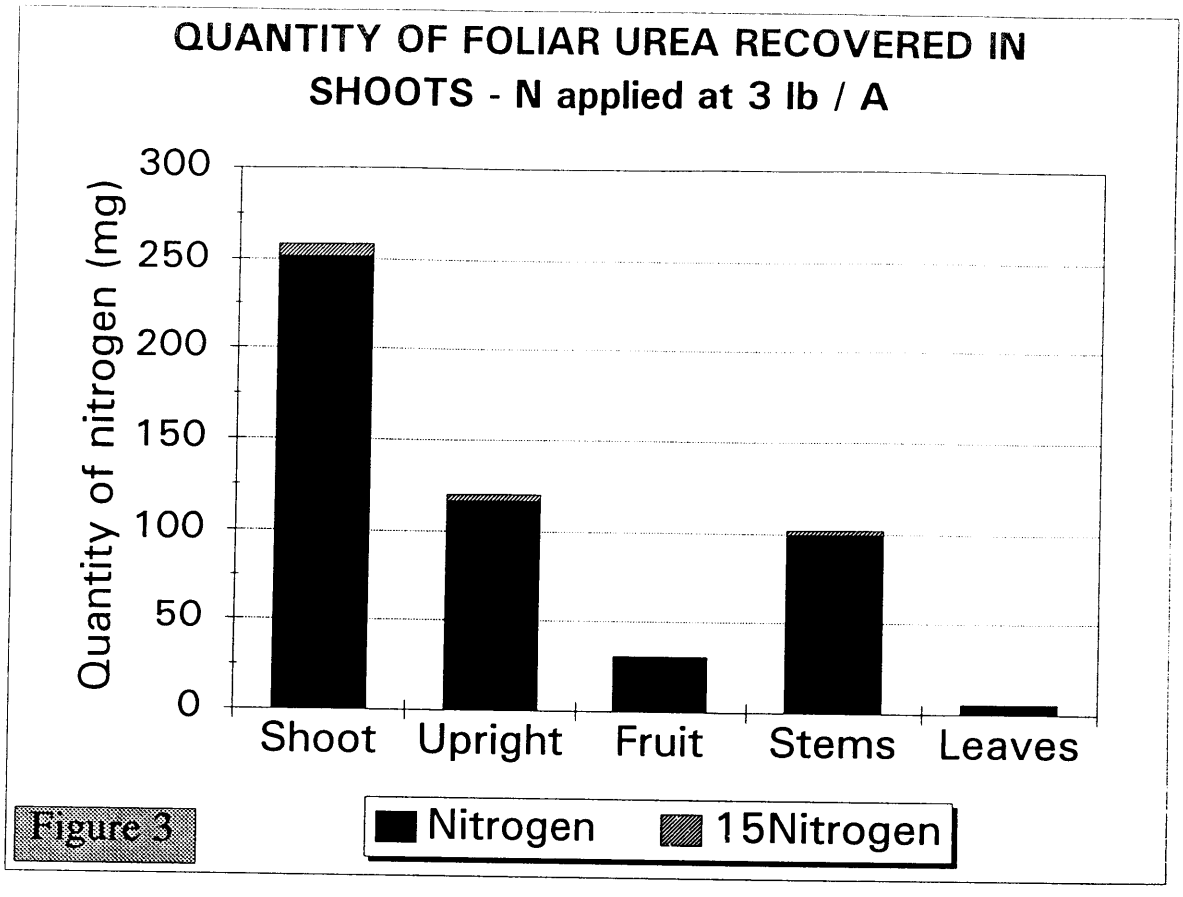

Figure 3

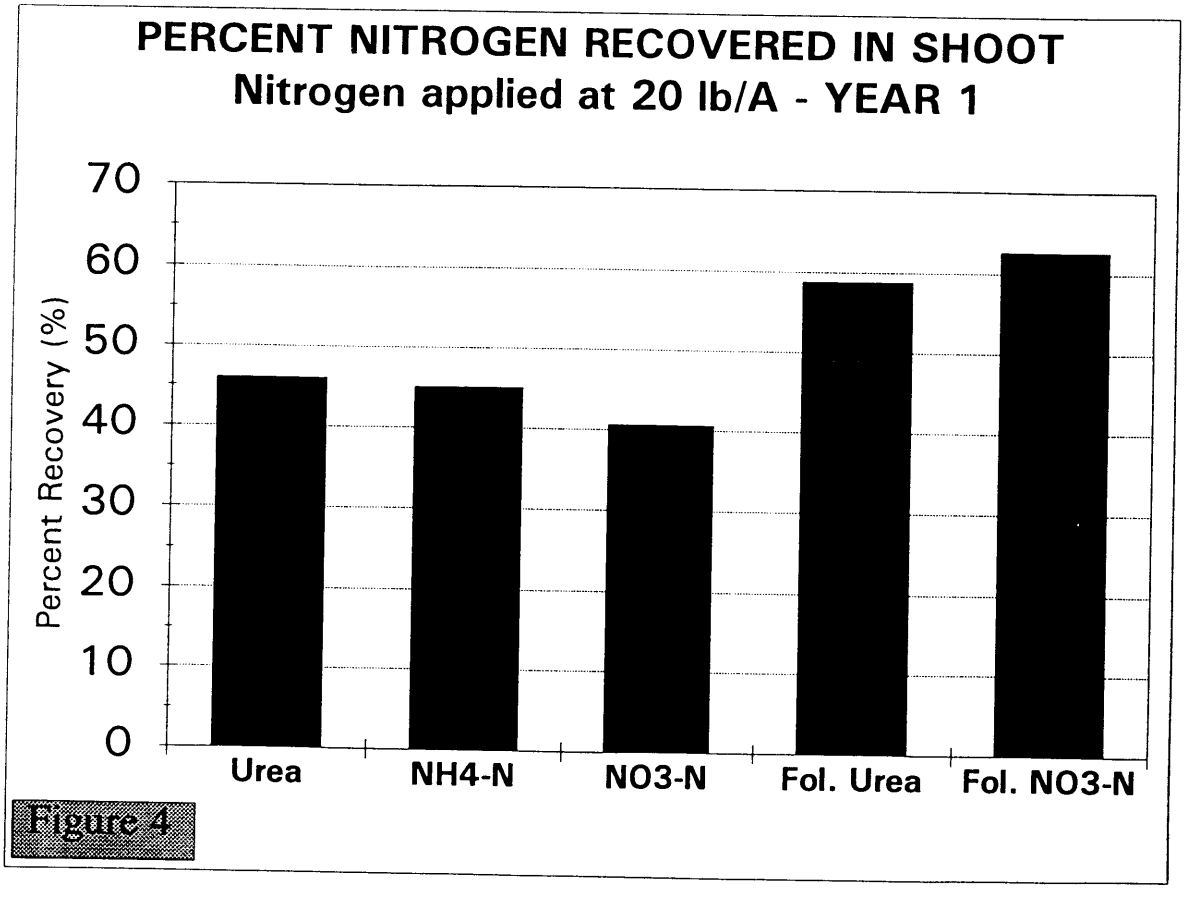

Figure 4

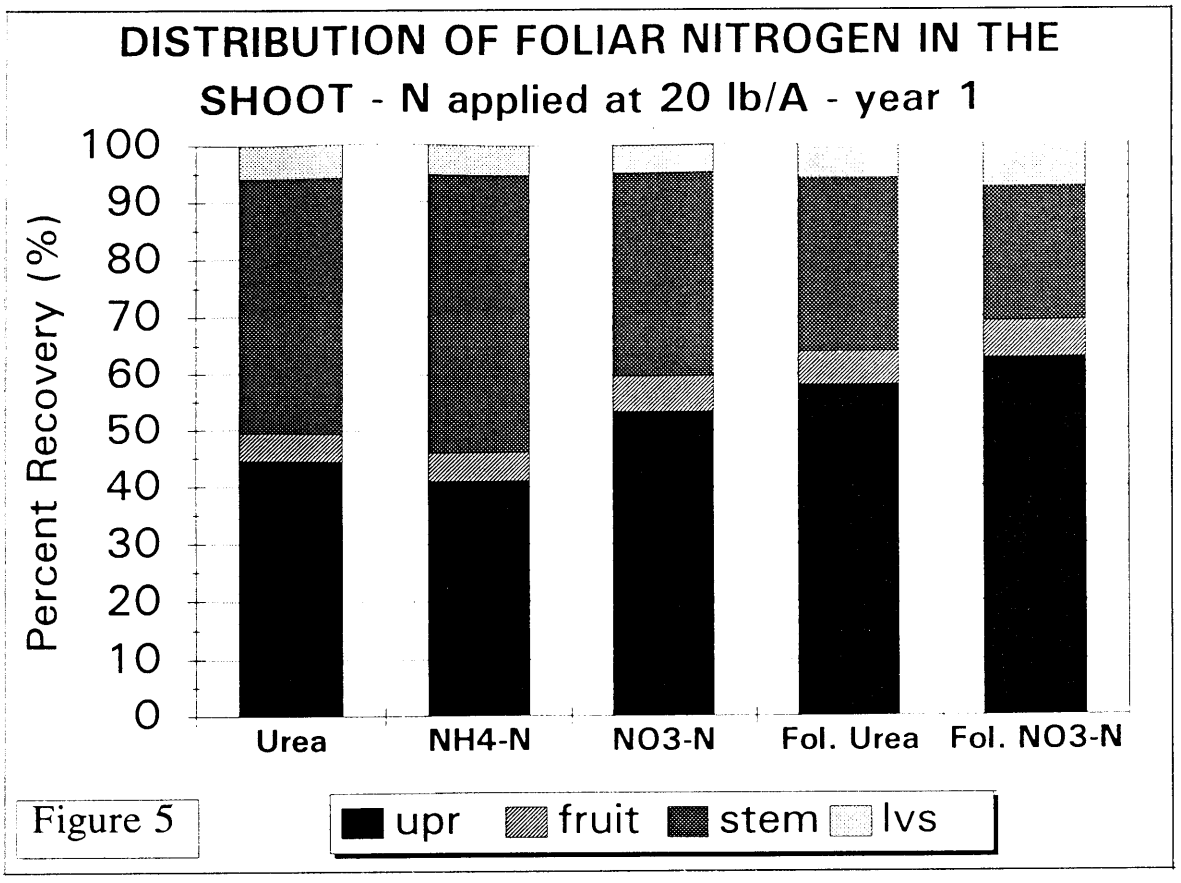

Figure 5

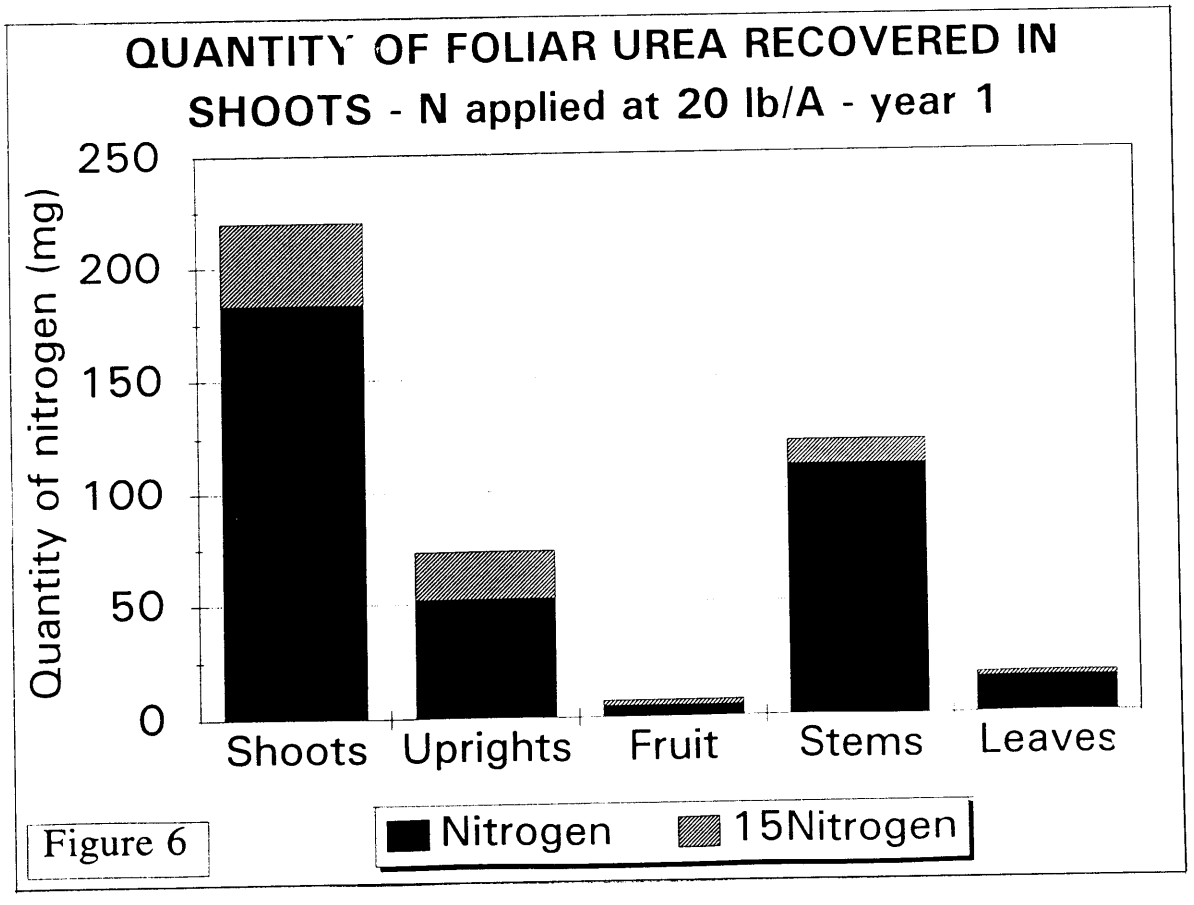

Figure 6

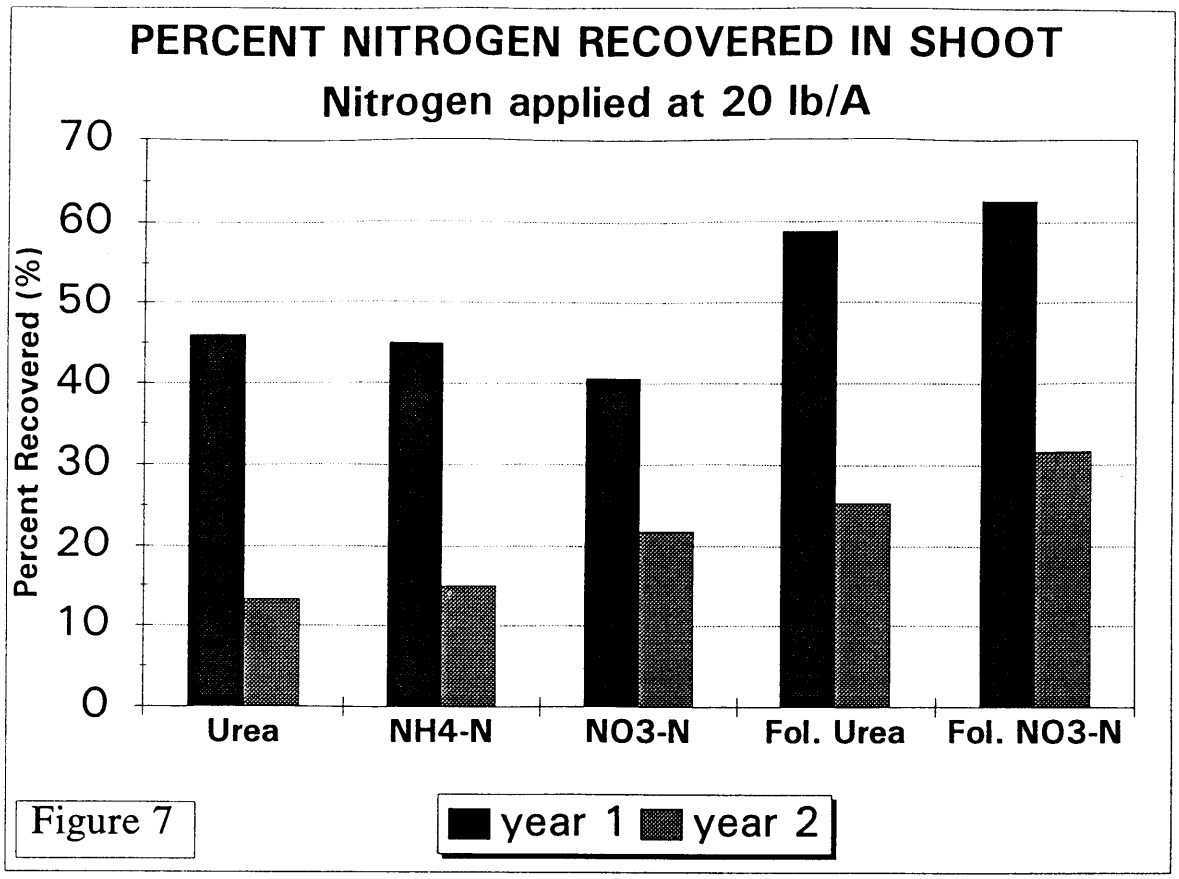

Figure 7

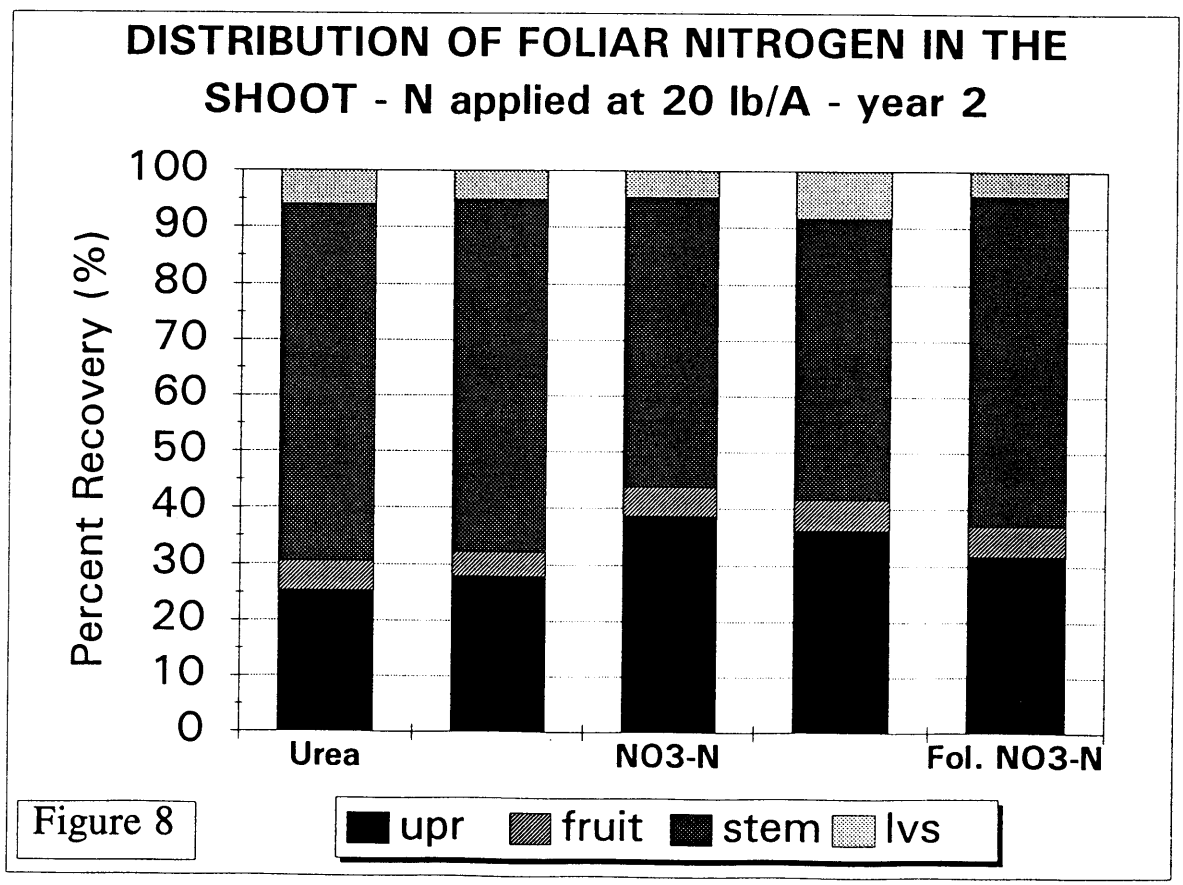

Figure 8

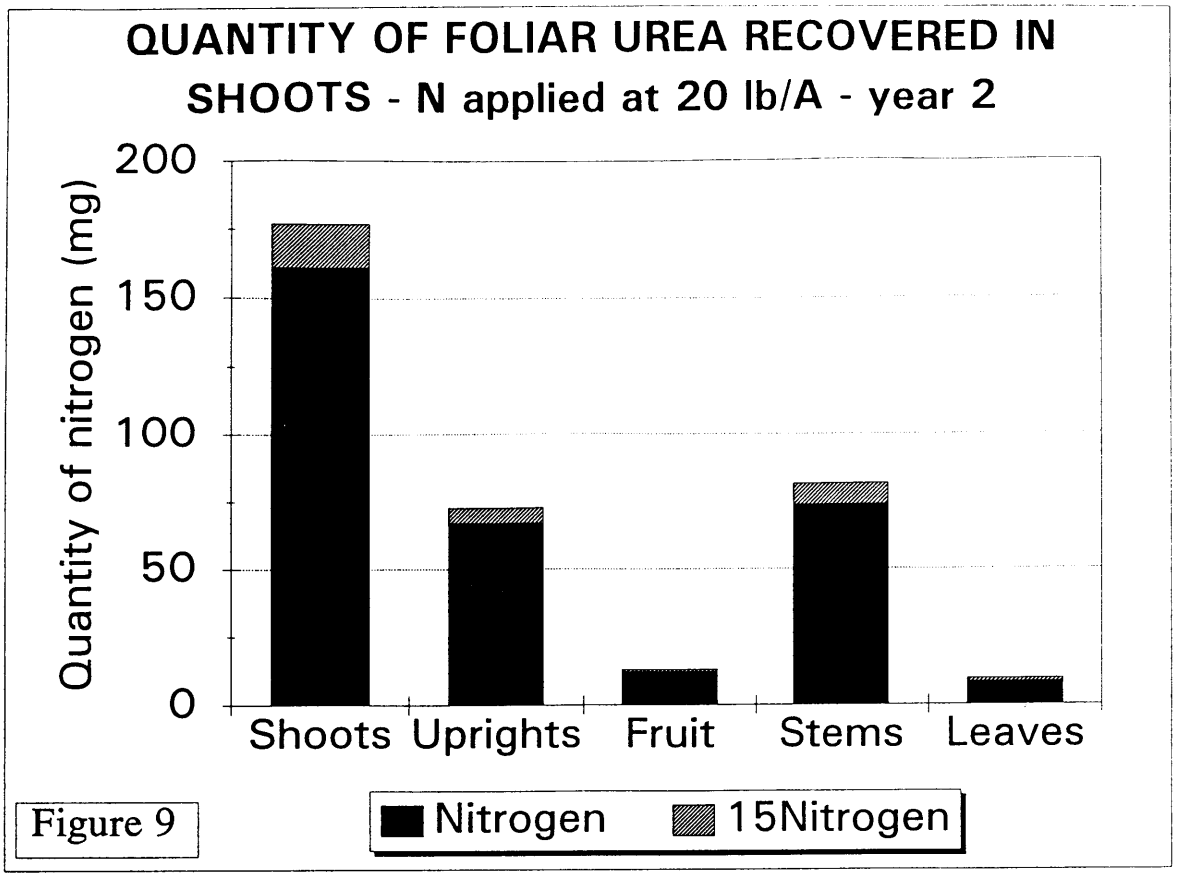
QUANTITY OF FOLIAR UREA RECOVERED IN SHOOTS - N applied at 20 lb/A - year 2
Quantity of nitrogen (mg)
200
150
100
50
0
Shoots
Uprights
Fruit
Stems
Leaves
Nitrogen
15Nitrogen

Figure 9

MINERAL DEFICIENCY SYMPTOMATOLOGY

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To profitably grow any crop, it is important that the factors necessary for desirable plant growth be available to the crop. To control all of the plant growth factors under field conditions is not possible. As seen in the last few years, such environmental factors as cloudy conditions, low seasonal temperatures, and excessive rainfall can affect cranberry production. An area where a four degree of control can be exercised is assuring that the nutritional requirements of the crop are met. To assist growers in defining the nutritional status of their crops, there are three diagnostic methods which are available, namely, 1) soil testing, 2) plant analysis, and 3) visual observation. A research base is necessary to assure that these methods can be used effectively. As you are well aware, soil and plant testing standards have been developed for cranberries and can be used to assist in diagnosing the nutritional status of your crop. To specifically define whether nutrition is or is not a problem in your crop is helpful and important.

Visual observation is a very practical procedure for assessing the nutritional status of the cranberry crop. A normal plant appearance and satisfactory crop yields would indicate that the nutrient level in the crop is adequate or sufficient. However, if the concentration of a nutrient is below the critical value in the plant, plant functions will be disrupted, and symptoms will occur. The severity of the symptoms will increase with a decrease in concentration below the critical value. A common symptom for all plant nutrient deficiencies is reduced plant growth. Other than reduced growth, visual symptoms will vary with the particular nutrient. Plant symptoms may appear in any of the organs including leaves, stems, roots, flowers, fruits and seeds. Without definitive symptoms, assigning the problem to a particular nutrient is difficult. Some degree of uniformity is essential for making the right diagnosis.

An attempt to develop and define deficiency symptoms for 11 nutrients elements on cranberry plants was conducted under greenhouse conditions using a hydroponic system. For the micronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) rooted cranberry cuttings were grown in a complete nutrient solution for 9 weeks. Excellent growth occurred during this period. After 9 weeks, plants were transferred from the complete nutrient solution to a solution containing all the nutrients minus the element to be tested. In the absence of each of the nutrients, growth was affected in 10 to 15 days and symptoms were present.

A slightly different technique was used for the micronutrients (zinc, copper, manganese, boron and iron) because it was previously observed that there can be enough of the micronutrient in the cranberry cutting to supply growth for an extended period. From a previous study for manganese, it was observed that there was enough manganese in the cutting to sustain the plant for 20 weeks before symptoms appeared. High manganese concentrations is not unusual under Wisconsin conditions because of the acid soils in cranberry bogs. For the micronutrients, the

rooted cranberry cuttings were started in the complete nutrient solution minus the particular micronutrient at the beginning of the experiment.

Besides observing the symptoms for each nutrient, the effected plant part was analyzed for its elemental composition for comparison with the standards for cranberry tissue samples.

Our observations indicate that the deficiency symptoms associated with particular nutrients on cranberry plants are quite difficult to define. Some of these symptoms will be discussed.

HOW MUCH WATER EVAPORATES EACH DAY FROM A CRANBERRY MARSH?

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Cranberry plants love water. Perhaps the significant amount of time you spend maintaining equipment and structures that manage water on the marsh serves to remind you daily of the importance of water to cranberry production. Water enters and exits a cranberry bed by several pathways, most of which you can readily see. For example, rain and irrigation are inputs that you can see, feel, and easily measure. Water flowing in a ditch away from a bed is also easy to observe. There are two other pathways for water movement into and out of a bed that cannot be seen, and are hard to measure: movement up and down in the soil, and evaporation.

Why do we care what happens to water in a marsh? There is almost always plenty of it around, and pumping is inexpensive relative to the value of the crop. The reason we need to better understand the flows of water in cranberry production is because application of water in excess of what the crop needs drains through the soil, possibly collecting fertilizers and agricultural chemicals and carrying them away. Water that drains through the soil leaves the bed in the ditches or straight downward toward the groundwater. You went to the trouble and expense of applying these chemicals, so you want them to remain and work as planned., and users of the water downstream may object to their presence. By understanding the behavior of water in the cranberry system, you can better control how much is available to possibly carry chemicals away from your marsh.

The Water Budget

The amount of water that flows into a cranberry bed must, over a period of a week or so, equal what flows out. This is because water is neither created nor destroyed within a marsh (or most anywhere else). As a result, we can write what we call a water budget. To clarify how a water budget works, think of a personal financial budget. I once asked the field manager at the Potter and Son Marsh in Cranmoor (who shall remain nameless) how much he would pay me to work there during my vacation. He had watched me doing research on his marsh and said he figured I was worth about $2.50/hr. For a forty-hour week. (which is the most anyone there has to work), I would be paid $100. My budget for the week would then be:

Income	$100
Tax	-$13
Food	-$65
Savings	-$5
Gas for car	-$15
Lottery or Throw-out	-$2
Balance	$0

So inflow and outflow of money is in balance. A water budget works the same way; for example, using numbers that could be gallons, liters, inches of water depth or an other unit of measure:

Rain+Irrigation	+100
Outflow in ditches	-15?
Flow up/down in soil	-15?
Evaporation	-75?
Change in water stored in the soil	+5?
Balance at end of week	0

The only thing I did not put a question mark after is rain+irrigation, because it is fairly straight forward to measure (use Hawaiian Punch cans; other beverage containers that you might have around do not have flat bottoms). We could measure flow in ditches with special flumes and height measuring devices, and changes in the amount of water stored in the soil could be determined in a number of different ways. The remaining two pathways, flow in the soil and evaporation, are tricky to measure. Although the water in soil is liquid and so visible, the soil is hard to see through. There is no way to measure this with confidence in a particular field. For research one can construct what is called a lysimeter, which is a large (say 10' square by 3'deep) box on a scale filled with soil and planted to cranberry. Then the total water flow into or out of the bottom of the soil can be measured. Note that this flow can go in either direction: it could be a source of water for the crop, or a pathway for loss.

At last we come to the topic of this paper, evaporation (also called evapotranspiration, ET). This loss occurs as water vapor, so we cannot see it with the naked eye. Radar-like devices now being developed can create images of the vapor above a field, but the amount of water escaping is hard to estimate by this technique. Fortunately, there are several research instruments that allow us to measure the rate at which water is evaporating from a field.

What We Did

Last summer we measured evaporation from a bed at the Potter and Son marsh, Cranmoor, using the Bowen ration technique. This involved very carefully measuring air and dewpoint temperatures at two heights, and some other things such as solar radiation and soil temperature. The equipment was fairly reliable compared to most research instruments, and we considered getting 28 days of good data during the whole summer a triumph.

What We Found

Evaporation rate during the course of a single day is shown in Fig. 1; the rate is expressed in inches/hr, just as you think of the depth of water from a rainstorm or irrigation. Also shown is the net radiation, which consists of radiation directly from the sun, plus that from the rest of the sky, minus the amount reflected (and re-radiated, technically) from the ground. Net radiation is by far the major energy source for evaporation in Wisconsin and similar humid areas. Net radiation, and evaporation, closely follow the daily cycle of sunshine.

When attempting to fill out a water budget, however, We are more interested in daily total evaporation so all of the (40-min) rates, like those shown in Fig. 1, were summed for each day. Values of total ET for individual days ranged from 0.04" to 0.22", depending mostly on the sunshine that day.

This is fine, but is it possible to estimate evaporation, rather than measure it with delicate and complicated instruments not designed for routine use? One of the main purposes of our research was to determine if the procedure we use to estimate evaporation from irrigated potatoes applies to cranberry. We make these estimates every day of the growing season from data collected by the weather station on the Potter and Son marsh, and at 19 other stations around the state. The advantage of using a prediction is that the weather station is designed to operate continuously and require little maintenance, while the measurement system is for research use only. The preliminary results of the comparison are shown in Fig. 2. In general, agreement is good between the measured and predicted daily evaporation amounts. A few days had discrepancies that are unacceptably large (0ver 0.05"). The source of these errors could be either the measurements or the model. We may have overlooked some problem with the Bowen ratio device on that day, or weather conditions may have been peculiar in some way that causes the prediction to fail.

In conclusion, the evaporation estimates currently produced by the University of Wisconsin Agricultural Weather Observation Network are reasonable for use with cranberry. These estimates are made early each morning for the previous day. They are available on the University of Wisconsin Extension computer bulletin board WISPLAN (along with other weather information) for a nominal fee. Contact WISPLAN at 608-262-4552. Telephone access to the data is available anytime from a computer synthesized voice by calling 800-263-4264. As a first step toward better understanding the behavior of water on your marsh, keep a record of predicted ET losses and compare it to rain and irrigation inputs over several weeks. Hopefully, your water applications are not too much in excess of the crop's ET, so drainage through the soil is controlled.

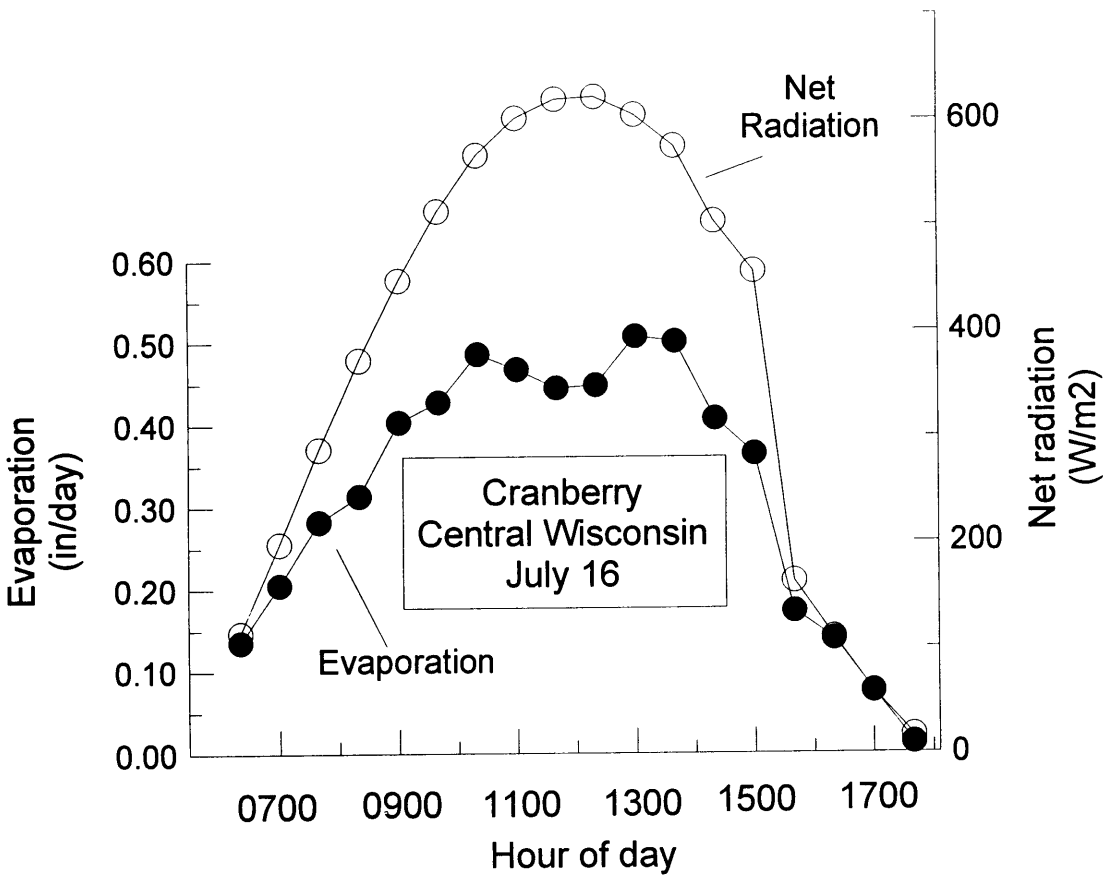

Figure 1. The net radiation and measured evaporation rate from a cranberry bed in Central Wisconsin on July 16, 1993. The evaporation closely followed the net radiation, which in turn closely followed sunshine. The total amount of evaporation on this day was 0.2 inches.

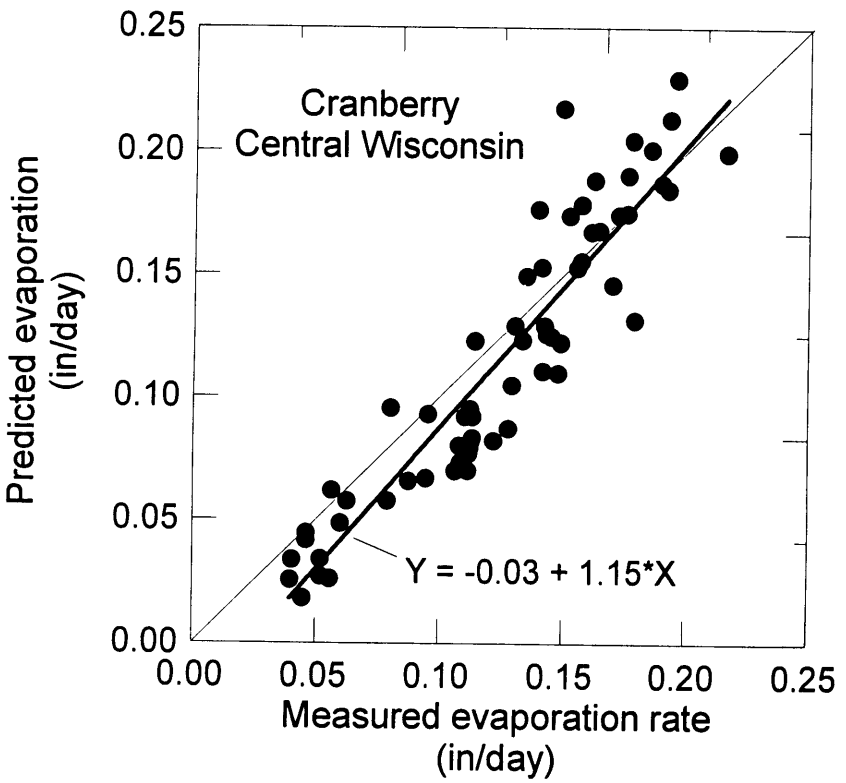

Figure 2. Comparison of measured daily total evaporation with that predicted from data collected by an automated weather station. If our measurements agreed perfectly with the predictions each day, all points would be on the diagonal 1:1 line. Agreement is generally good, although there are unacceptable discrepancies (over 0.05"0 on several days. We do not know if these were due to an undetected error in our measurement, or in the prediction method.

SANDING: OUR CURRENT UNDERSTANDING

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The practice of sanding is thought to have begun with Henry Hall of Barnstable, Massachusetts in 1816. When sand blew from a knoll onto a section of wild cranberries, he noticed the condition of the vines improved. The idea of improving cranberry marshes via sanding began early and has been followed more or less diligently since then. Substantial misunderstanding and misinformation exists about sanding. Dr. F.B Chandler writes "When Director Sievers hired me, he asked me to get rid of sanding and said that it was an expensive method not used for any other crop." Dr. Chandler then goes on the extol the virtues of sanding. Some of these are listed below.

Benefits of sanding

The benefits associated with sanding are many. Unfortunately, for most of these no good research data is available to provide quantitative measures of the benefits of sanding. I have gone back through the available literature and have tried to summarize the documented work.

Insect management

Much has been written about sanding as an insect management practice. Sanding has been advocated for controlling both tipworm and girdler. The latest research suggests that sanding will temporarily suppress tipworm populations by burying overwintering tipworm pupae. However, the benefit will last at most one year. Tipworm populations in beds increases quickly after sanding either from adjoining unsanded beds or from bed edges that are more likely to be unsanded.

Sanding does produce higher mortality of cranberry girdler larvae. Research in British Columbia show higher survival in the duff layer than in sand.

Prunes vines and encourages rooting

This is probably the best documented aspect of sanding. Horticulturally sanding is similar to pruning. It "removes" dead wood. Other perennial fruit plants are selectively pruned to remove unproductive wood. Low bush blueberries are burned periodically to remove unwanted wood. Sanding provides a similar function in cranberries. Woody runners under the canopy do not send down roots into the soil. However, runners that are covered with sand produce roots in the new layer of sand. This keeps the distance between roots and buds as short as possible. Some few uprights may also be bent down as the sand settles, thus improving light relations within the cranberry canopy.

Actual vine pruning where runners are cut and uprights and runners are removed from the bed will accomplish much of the same results over time.

Drainage and aeration

Since coarse sand is used when sanding movement of air and water through the new layer is improved. Since coarse sand has relatively large particle size the pieces fit together poorly leaving air pockets between the particles. Oxygen can diffuse through the sand layer easier than through thick duff or finer soils. Since cranberry roots are alive, they require oxygen to grow and function. Oxygen can reach the roots only through the soil.

Water is held on the surface of soil particles. Since sand has a relatively small surface to volume ratio, it cannot hold much water Excess water drains into lower soil layers. Improving soil drainage would be sufficient reason to sand even if no other benefits resulted.

Soil radiation

An exposed sand layer will capture and release more radiant heat than a duff layer. This can be important on a frosty night. Measurements in Massachusetts suggest that a newly sanded bed may be 2°F higher on a frosty night than an unsanded bed.

Some people have suggested that a newly sanded bed will reflect light back into the canopy thus increasing the rate of photosynthesis. I know of no data to support these statements. This would only be true if light were the limiting factor for photosynthesis on a given day. Our research has shown that cranberry photosynthesis saturates for light at about 60 to 70% of full sunlight. On a sunny day or a lightly cloudy day photosynthesis is probably not limited by light. Adding more light under these circumstances will not increase photosynthesis anyway.

Weed management

There are mixed results and interpretations of the effects of sanding on weed development. Traditional wisdom is that sanding covers weed seeds and small annual weeds and smothers them. On the other hand it hold moisture and may provide ideal conditions for germination. After sanding weed seeds that blow onto a sanded bed also find ideal conditions and a more open canopy thus improving their chances for survival. Sanding affects perennial weeds much the same as cranberries and may actually invigorate their growth.

Sanding is thought to enhance the effectiveness of many of our herbicides. Herbicides may be "tied up" by the organic matter in soils. Sanding covers the duff layer and allows herbicides to retain activity in the low organic matter sandy layer. As a result growers can use a reduced herbicide rate and still get acceptable results.

Sanding practices

There is a certain amount of variability between growers for all cultural practices. Sanding is no exception. Sanding practices are likely more easily justified on an economic basis than a biological basis. How deep to sand, how often to sand and what time to sand are determined more by costs and benefits than absolute biology. A discussion of sanding practices follows.

Sanding depth

Very little is known about the proper depth of sanding from the scientific literature. Our practices are based on experience and practicality. Generally in Wisconsin 3/4 to 1 inch of sand is spread on the surface of the ice in winter. Research in Oregon (where there is no winter flood) demonstrated that yields are reduced in the year of sanding when 1 inch of sand is spread but not when 1/2 inch is spread. However, the benefits of sanding are lost the year following 1/2 inch sanding, but yields are improved the year following 1 inch sanding (Strik, unpublished data). One of the strong determinants of sanding depth is the amount of sand that must be applied per acre. While the requirement for sand is linear, costs also increase while the benefits of sanding will be lost or be marginal at some higher sanding depth. Again, sanding depth is likely more an economic question than a biological question.

Frequency of sanding.

I could find no citations in the literature showing experiments on the correct frequency of sanding. There was general agreement that in most cases with good marsh management sanding every 3 to 5 years was adequate. Again, frequency of sanding is an economic question not a biological question. Newly planted beds are frequently sanded each year for the first 2 or 3 years to encourage rooting and runner development and to anchor the vines before harvesting.

Time of sanding

This is one area where there has been a lot written. Some old literature suggests that sanding should be delayed as long as possible so as not to block light that may reach the vines. This light would allow plants to photosynthesize and release oxygen that could be used for respiration. Growers fear that if they sand early that leaf drop will follow in the spring. Unfortunately, in my opinion, this recommendations are based on a poor understanding of cranberry biology. In Wisconsin, sand can be applied anytime there is thick ice on a bed. The limitation is the ability of the ice to support the weight of a dump truck and sander. Following is a discussion of the reasons why I think time of sanding is irrelevant in cranberry culture.

Rationale discussion

There is a voluminous literature explaining the need for dormant cranberry vines to have sufficient oxygen. Dormant cranberry vines do need oxygen as all living organisms do. Oxygen is required for respiration which is the process of converting the chemical energy in food to energy usable for cellular functions.

Air contains roughly 21% oxygen and most of the balance is nitrogen gas. Oxygen moves primarily by diffusion. Water also contains oxygen. The ability of water to hold oxygen is related to its temperature. Cold water can hold more oxygen than warm water. The saturation values for water's ability to hold oxygen at different temperatures are 10 ml/l at 32°F, 8.7 ml/l at 40°F and about 7.8 ml/l at 50°F. As water temperature increases its ability to hold oxygen decreases.

The rate of respiration in plants respond to two primary factors. The first is temperature. As the temperature rises the rate of respiration increases. In the normal range of temperatures, respiration doubles when the temperature increases by 10C. At temperatures at or below freezing the rate of respiration is very low, so the need for oxygen is also very low. Plant respiration also responds to oxygen availability. As oxygen concentrations surrounding plants decrease, the rate of respiration also decreases. This is the basis of controlled atmosphere storage for apples. Apple growers keep storage temperatures near 32 and oxygen concentrations between 2 and 5% by volume. By doing so apple respiration slows markedly.

In plants, the inverse process of respiration is photosynthesis. Photosynthesis has two parts, the "light reactions" where light energy is harvested and oxygen is released. These functions are almost temperature independent, meaning they will proceed at most any temperature if light is present. The second part of photosynthesis are the "dark reactions". In these reactions, the harvested light energy is used to "fix" CO_2 into carbon containing sugars. These reactions are very temperature dependent. Virtually no CO_2 is fixed in vines under ice in the winter. Both temperatures and CO_2 concentrations are limiting. The problem occurs when the "light reactions" are still proceeding, but the dark reactions are stopped for whatever reason. When this happens there are high energy bonds and molecules in plants with nothing to do. Over time, these reactive molecules can actually disrupt the plant cells and cause injury or death.

We think that one reason plants like cranberry turn red in fall and winter is to protect the photosynthetic apparatus of the leaves from injury. The red pigments reflect some light to protect the cells. It follows that they are less efficient at capturing light and transferring it to chlorophyll. If this is true, low light would be more beneficial to overwintering vines than high light.

Using very crude instrumentation, light levels under ice were measured in Massachusetts between 1938 and 1942. In general they found that ice alone (ranging from 4 to 8 inches thick) blocked between 20 and 60 percent of the light incident on the top of the ice at solar noon. By afternoon when the sun was lower on the horizon the levels were always lower. Other factors that influence light penetration through ice are the amounts of solids and debris in the ice, the amount of snow on or between ice layers, and the crystal size of the ice. In Massachusetts, only about 5% of incident light penetrated 4 inches of snow.

Back to sanding practices. You are probably wondering what all this has to do with sanding on ice. It is my opinion that time of sanding doesn't make any difference. First, oxygen requirements for respiration are *very* low when the vines are dormant. Second, plants don't need or want much light during the winter. Light can actually be damaging to dormant vines. Third, oxygen evolution via photosynthesis would be very low if only from the light limitation from ice and snow. Very little light is needed to produce some oxygen through photosynthesis that could subsequently be used for respiration.

The typical explanation given to me for late sanding or plowing snow from ice in winter is leaf drop. During dark, cloudy winters or snowy winters growers remember having more leaf drop than during more "normal" years. Leaf drop may also be greater around bed edges where snow tends to accumulate. I can't dispute your observations. However, a correlation does not establish a cause and effect relationship. Let me offer some alternative interpretations.

Dr. Frank Caruso of the University of Massachusetts associates significant leaf drop with beds that have cropped heavily the year before. What may be happening here is that carbohydrate reserves are too low following a heavy crop and leaves drop from lack of resources. Virtually no CO_2 will be fixed under ice in winter, so all energy needs for respiration must come from storage compounds.

Because of the risk of dropping a loaded dump truck through the ice on the edges of beds, growers tend to sand bed middles preferentially to bed edges. Over time the bed edges may be significantly lower than the middles. This would lead to poor internal soil drainage on the bed edges. Poorly drained soils are more likely to be anaerobic, leading to leaf drop.

The other observation I would offer is that larger growers who must begin sanding early in order to get their sanding done don't suffer ill effects from early sanding. This inconsistency alone should be enough to question the issue of early *vs.* late sanding.

Conclusion

Sanding is a beneficial cultural practice that has been shown to invigorate plantings and increase yields over time. Many of the issues regarding sanding are best examined from their economics in terms of what does it cost to sand, yield loss in the year of sanding and increases in yield that may be realized in subsequent years. Economics will also guide frequency of sanding.

The proper time to sand is more a function of convenience than of blocking light to vines. Given the choice between sanding early and not sanding because of rotten ice, I would sand early.

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GYPSY MOTH: A FUTURE WISCONSIN CRANBERRY PEST?

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The gypsy moth, *Lymantria dispar*, which is native to Europe and Asia, was purposefully brought into Massachusetts in 1869 by a Frenchman who wanted to cross it with the silkworm to improve the fledgling U.S . silk industry. Not only was this a foolish and impossible venture, the gypsy moths escaped and became established. It has since spread throughout the northeastern United States and adjacent Canada, where it has become a serious pest. In recent years, significant numbers have been found in eastern Wisconsin.

Gypsy moth is normally considered to be a pest of trees, especially deciduous trees. Areas most vulnerable to gypsy moth attack are forests, parks, recreational areas, and urban forests (street and home yard trees). The gypsy moth larvae are known to feed on over 300 types of trees and shrubs, including nursery stock and fruit crops. In Massachusetts and New Jersey, gypsy moth is an occasional pest of cranberry, and has the potential of causing significant injury, especially in those years during an outbreak period, when growers must routinely monitor for activity in the beds and be prepared to apply appropriate controls. This paper summarizes the biology of gypsy moth, its status in Wisconsin, and its potential threat to the cranberry industry.

BIOLOGICAL CHARACTERISTICS

The gypsy moth is a relatively large insect. The male is dark brown, with a wingspan of about 1.5 inches. The female has white wings with thin, wiggly dark stripes; her wingspan is about 2 inches. Although she has fully developed wings, the female is flightless, but males are strong fliers. Adults occur in July and August. The female produces a sex pheromone for luring the male. Immediately after mating she begins to lay a single large egg mass that may contain up to 1,000 eggs. The egg mass is covered with buff-colored hairs from the female's body. Because the female doesn't fly, the eggs are laid wherever she happens to be. This is usually on the trunk or branches of a tree, but may also be on rocks, walls of buildings, vehicles, or any other surface. The insect remains in the egg stage through the remainder of the summer, fall, and winter. Hatching occurs in May about the time oak leaves start to develop. Gypsy moth larvae are densely hairy caterpillars that grow to about 2-3 inches long. Down the back of the caterpillar there is a double row of 5 blue spots followed by a double row of six brick-red spots. Several other large, hairy caterpillars are confused with the gypsy moth. Most frequently, eastern tent caterpillar, which makes dense silken webbing, is thought to be gypsy moth, but gypsy moth does not produce webbing. Larvae feed until mid to late July, and then pupate in protected areas on or at the base of trees. Adults emerge about two weeks later, completing the one generation per year.

STATUS OF GYPSY MOTH IN WISCONSIN

Because of the serious nature of gypsy moth, it is a quarantine pest in the United States. Forest and nursery products produced in quarantined areas must be inspected and, if necessary, treated, before they can be shipped to uninfested areas. Furthermore, federal and state agencies monitor gypsy moth activity throughout the United States. The primary method of monitoring is the use of pheromone traps similar to those used for monitoring cranberry pests, but baited with the gypsy moth pheromone. When males are captured in a new area, an intensive search is conducted the following year for more males or other life stages.

Gypsy moth is appropriately named. Adult males can fly into trucks, vans, boxcars, trailers, or automobiles and be transported hundreds or even thousands of miles. Therefore, if a single isolated male is captured, it is often just a "hitchhiker" with no significant consequences. However, multiple catches in the same area usually indicate the start of an infestation. Not only is the male moth likely to move around, so are the egg masses, especially when the eggs are laid attached to vehicles or objects about to be moved across country. Because a single egg mass can produce several hundred larvae, this is by far the most important method of spread of gypsy moth. Once a federal or state agency identifies a new small infestation in an uninfested area, the first approach is to eradicate the infestation using a pesticide. In Wisconsin and many other areas, the pesticide of choice is one containing the active ingredient *Bacillus thuringiensis* (Bt). It is important to note that, as long as there is possibility of eradicating or greatly slowing the spread of an infestation, responsibility and authority for control resides with state and federal agencies. However, once the decision has been made that eradication is not going to be successful, then control is the responsibility of the property owner.

Gypsy moth males were first trapped in southern Wisconsin in the 1970s. Since then, some have been trapped each year. Throughout this period, numerous positive infestations have been identified, often traceable to the movement of vehicles, merchandise, or household belongings. In the late 1980s, lower Michigan was declared to be generally infested, and eradication efforts ceased. Since that time, gypsy moth activity has significantly increased in Wisconsin, especially in, but not limited to, the northeastern corner of the state (Door and Kewaunee Counties), and south along the shore of Lake Michigan. Two theories have been proposed to explain the current area of activity: vacationers unknowingly transporting egg masses, and young larvae being blown across Lake Michigan from lower Michigan. In 1993, several thousand acres in Wisconsin were treated with Bt. It is likely that the Wisconsin infestation will continue to increase in size until regulatory agencies decide that the state is generally infested. How many years in the future this will be is anyone's guess. However, lower Michigan went from 8 acres defoliated in 1980 to 750,000 defoliated in 1993. (Defoliation is defined by visual loss of foliage when viewed from the air, equivalent to at least 60% leaf loss.)

Although the state of Wisconsin is putting most of its monitoring efforts into the eastern side of the state, and in vulnerable areas such as port cities, some trapping is done throughout the state. Thus far, most trap catches have been in the southern and eastern parts of the state, but there have also been small numbers captured in central and northern counties. In 1993, approximately 70,000 traps were operated throughout the state. From

1990 to 1992, approximately 10-15,000 males were trapped annually; that number rose to 36,000 in 1993.

POTENTIAL THREAT TO WISCONSIN CRANBERRY PRODUCTION

The potential success of gypsy moth in Wisconsin can only be conjectured. It has ample favored hosts (such as oaks and poplar) and many acceptable hosts (even including conifers) throughout the state. One question regarding its success here relates to its tolerance of our harsh winters. Gypsy moth eggs cannot survive temperatures below about -18 degrees F. However, many egg masses may be laid close to the ground where they may be protected by snow. We won't really know how well gypsy moth will survive and prosper in the state until it actually becomes established here.

In the eastern United States, gypsy moth can present a problem to cranberry at two points in its larval growth. Very young hatchling larvae tend to spin a small amount of silk and allow the wind to carry them into new areas; this is the primary natural way of gypsy moth dispersal. If there are infested woods near cranberry, prevailing winds can blow young larvae into the beds, where they will feed on the new, young foliage and the terminal growth, effectively destroying the flowering potential of that upright. In the eastern United States gypsy moth goes through outbreak periods where millions of acres of forest are completely stripped of all foliage. When the larger caterpillars no longer have food to eat in the trees, they begin wandering in search of food elsewhere. Large numbers moving into a cranberry bed can do significant damage to uprights, buds, and flowers. Many beneficial natural enemies of gypsy moth have been introduced into the United States from Europe and Asia and are now permanently established. Some native beneficials will also attack gypsy moth. Biological controls are very important in suppressing gypsy moth populations, but are not currently able to keep the insect under permanent, economic control. However, federal and state scientists continue to look for natural enemies of gypsy moth throughout its native range of Europe and Asia.

Gypsy moth can be controlled in cranberry beds with both chemical (Orthene) and microbial (Bt) insecticides. Other insecticides aimed at fireworm or other insects will also control gypsy moth larvae. Insecticides will be most effective if targeted against young (1/2 inch) larvae.

CONCLUSION

It is likely that gypsy moth will eventually become established throughout Wisconsin. How long that will take is unclear, but it may happen before the turn of the century; the speed of its development in Michigan may serve as a model of what to expect. Also, it won't be possible to tell how serious of a pest it will be until it does become firmly established. If it does build up to numbers large enough to cause damage, it will be the responsibility of individual property owners to conduct whatever control they desire.The Wisconsin cranberry industry is fortunate to have adopted Integrated Pest Management practices including routine pest scouting. Thresholds for gypsy moth larvae, based on sweep net counts, have been established in Massachusetts. Pheromone traps are available. And both chemical and microbial insecticides are registered and effective. Gypsy moth may

be another critter to contend with in the future, but it is not going to pose insurmountable problems, especially if growers and consultants continue to be diligent about pest scouting.

For more information on the Wisconsin gypsy moth program, contact Mr. Steve Krause, Gypsy Moth Program Coordinator, Wisconsin Department of Agriculture, Trade, and Consumer Protection, Madison, at (608) 266-7136.