Nutrition of Blueberries & Implications For Fertilization

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Fertilizer requirements

How much does the plant need?

What is already available?

When does the plant need the nutrient?

How is the fertilizer taken up by the plant?
  How mobile is the nutrient?

What source of the nutrient is best?

Mobility in the Plant

- Mobile within the plant
  - N, P, K, Mg, Cl
- Immobile within the plant
  - S, Fe, Mn, Cu, Zn
- Very immobile within the plant
  - Ca, B

Translocation Within the Plant

- Xylem (Water Pipes)

  Dead: Everything goes to leaves with water
- Phloem (Sugar Pipes)

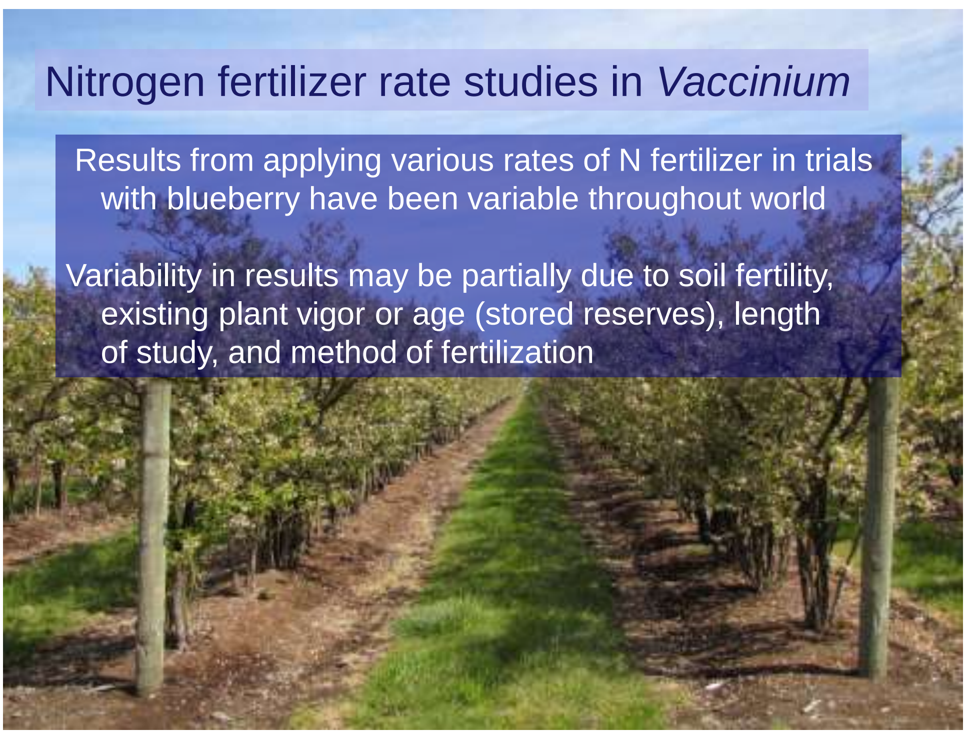
  Alive: To move something out of a leaf requires the phloem

Nitrogen

- Mobile in plant and soil
- *Vaccinium* plants take up ammonium (NH_4^+) form
- N is present in many essential compounds
- General chlorosis along with reddish tinge when deficient; poor growth
- Excess N will increase vigor, may decrease yield & quality

Nitrogen Source

- Blueberry plants use the ammonium form of N (NH_4^+)
- Fertilizer programs that contain only nitrate (NO_3^-) should be avoided!
- Do not use ammonium sulfate if the soil pH is below 5 unless you add lime



Nitrogen fertilizer rate studies – Granular

- In 5-year study on 'Bluecrop' in Michigan, split applications of 75 lb N/a had higher yield than no fertilizer (Hanson and Retamales, 1992)
- In Arkansas, yield of 'Collins', applying 65 or 130 lb N/a reduced yield compared to 20 lb N/a over two years (Clark et al., 1998) and in an 8-year study, there was no benefit to fertilizing with more than 30 lb N/a (Cummings, 1978)
- In Oregon, in a 2-year study in mature 'Bluecrop', there was no difference in yield between 0, 100, and 200 lb N/a (Bañados et al., 2006)

 and

- Fertilization with low to high rate (50 to 240 lb N/a) of N for 7 years in Elliott has had no effect on yield to date (Strik et al)

Nitrogen fertilizer rate studies – Granular

- In Oregon, in establishing plants, the best rate (of 0, 50, 100, and150 lb N/a) of granular in new fields was 50 lb N/a (Bañados et al., 2006)
- In an organic study in Oregon, the best rate of fish emulsion and feather meal was 25 and 50 lb N/a, respectively, in the first three years of growth. (Larco et al., 2011)

Fertilizer uptake and partitioning (^{15}N) Granular

Nitrogen fertilizer uptake studies using ^{15}N have been done in field-grown blueberry (Throop and Hanson, 1991; Retamales and Hanson, 1989; Bañados, 2006; White, 2006).

- Plants absorb fertilizer N more efficiently from late bloom through fruit maturity
- Fertilizer uptake efficiency from granular products is low, and thus multiple applications are recommended

Second application in May

Third application in June


‘Liberty’, 3-year old, Oregon
Drip irrigated and fertigated


Southern highbush, three-year-old, in California
Fertigated

Fertilization with drip irrigation "Fertigation"

Nitrogen fertilizer rate studies using fertigation are limited (Bryla, in progress; Finn and Warmund, 1997; Williamson and Miller,2009)

- In Missouri, northern HB blueberry had larger size and higher yield in year 3 and 4 when fertigated with N compared to same rate of granular N at bud break + 6 or 12 weeks – thought related to improved efficiency (Finn and Warmund, 1997)

- In pine bark system in FL, canopy growth and yield of Misty and Star increased with rate of N fertigated (likely due to limited water and nutrient holding capacity of bark) up to 260 lb N/a and
- Granular (applied monthly Mar-Oct) or fertigation every 2 weeks (Mar-Oct) led to slightly higher yield with granular (Williamson and Miller, 2009)

Fertilization with drip irrigation "Fertigation"

Nitrogen fertilizer rate studies using fertigation are limited (Bryla, in progress; Finn and Warmund, 1997; Williamson and Miller,2009)

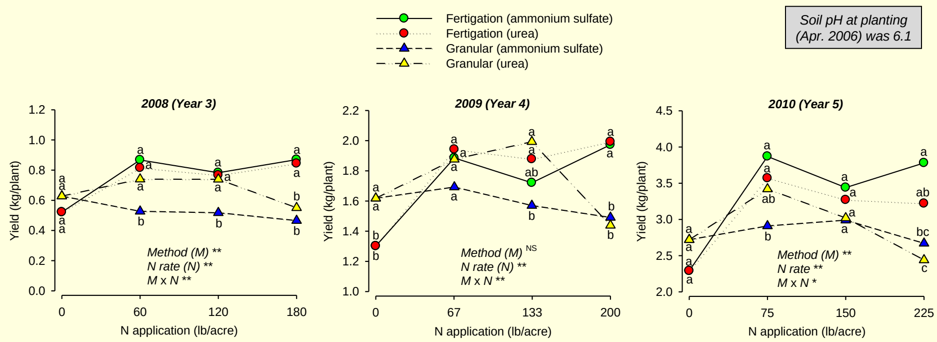
- In Oregon, granular with ammonium sulfate or urea & micro-spray sprinklers is being compared to drip fertigated at rates from 0 to 225 lb N/a

- In granular applications, high rates lead to high EC (salt) and plant stress

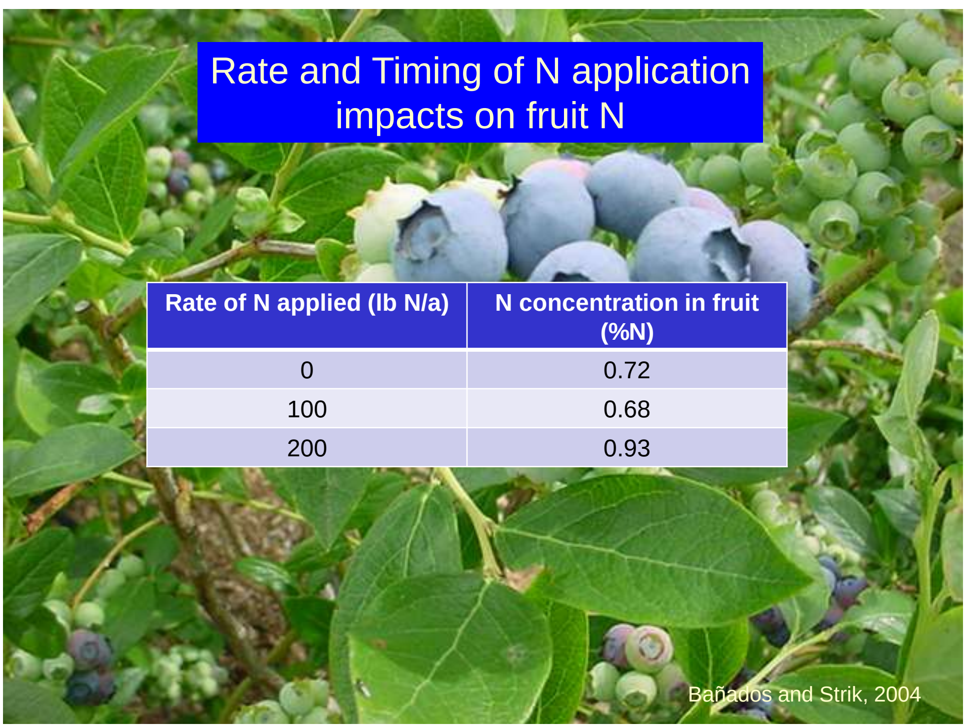
- In fertigated plantings, higher rates of N may not increase yield, but have not lead to salt injury to date

(David Bryla, USDA-ARS, Corvallis, work in progress)

Fertigation (drip) vs. Granular Fertilizer (sprinklers)



Vargas & Bryla (unpublished data)



Rate and Timing of N application impacts on fruit N

Rate of N applied (lb N/a)	N concentration in fruit (%N)
0	0.72
100	0.68
200	0.93

Bañados and Strik, 2004

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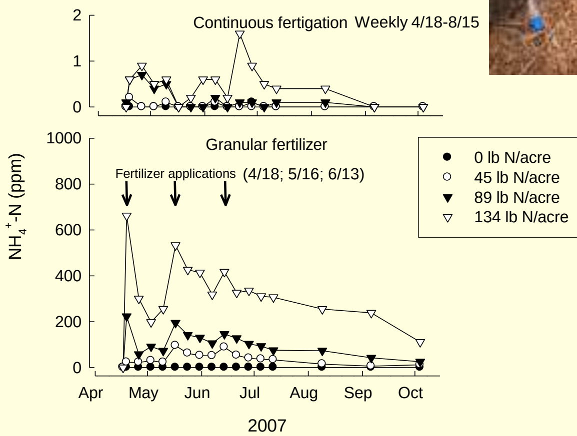
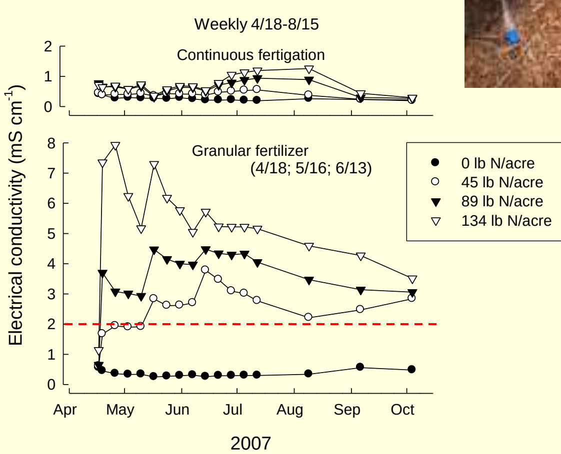


Courtesy: Dr. Dave Bryla, ARS-USDA, 2008



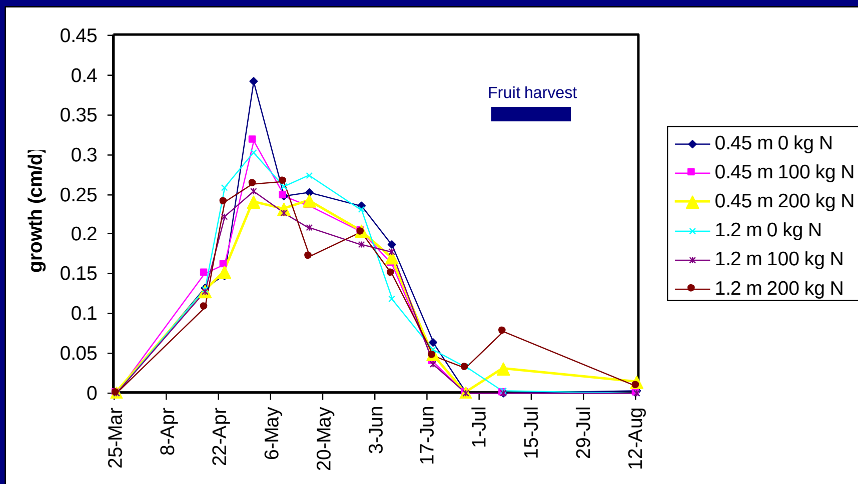
Courtesy: Dr. Dave Bryla, ARS-USDA, 2008

Nitrogen fertilizer rate studies

- N fertilization can increase yield through increased growth however, there is often a threshold
- N fertilization may impact next year’s yield through effect on flushes of growth and subsequent flower bud initiation and by increasing winter cold damage

Lateral shoot from one-year-old wood

Effect of N fertilization rate of ‘Bluecrop’ at 0.45 m and 1.2 m spacing on shoot growth in 2002

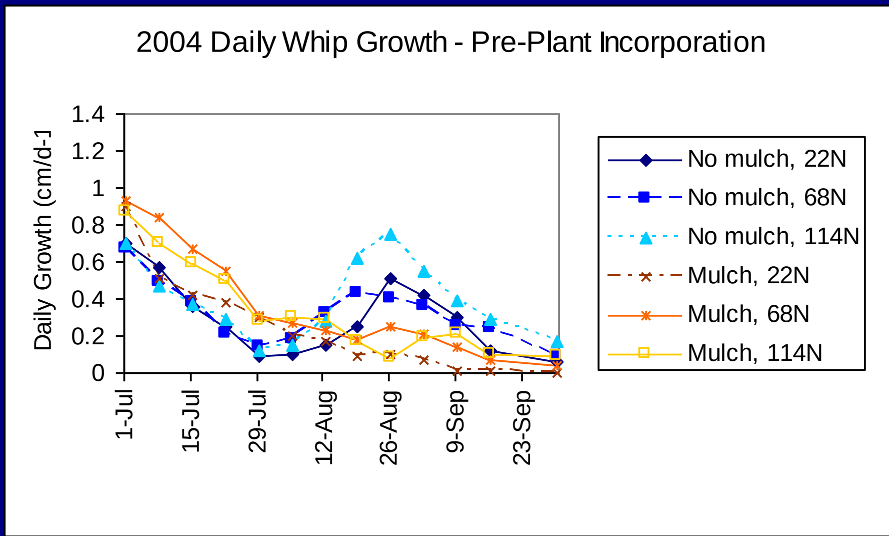


High rates of N force later flush of growth
Late fertilization with N forces late growth

} Reduce bud set
Increase cold damage

Bañados and Strik, 2004

Growth rate of whips in Elliott as affected by production system
Year 1



White and Strik, 2006

Liberty

How much N is tied up in fresh sawdust mulch?

- 3” deep 2’ wide sawdust mulch centered on rows:
- Fresh sawdust immobilizes 0.1 % N
- = 25 lb N/a

Fresh sawdust (C:N =800)

Yang,2005

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Adjust N fertilizer when using mulches based on C:N ratio


Weed mat, Duke, Oregon

Nitrogen (N)

- Mobile in plant and soil
- *Vaccinium* plants take up ammonium (NH_4^+) form
- N is present in many essential compounds
- General chlorosis along with reddish tinge when deficient; poor growth
- Excess N will increase vigor, may decrease yield & quality

Phosphorus (P)

Early season P deficiency due to cool soil temperature

- Mobile in plant, but very immobile in soil
- Involved in photosynthesis, other metabolic processes and part of DNA and RNA
- P deficient plants are stunted and often dark green; leaves may have red tinge due to accumulation of anthocyanins
- Excess P will increase root to shoot ratio

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Potassium (K)

K toxicity

- Mobile in plant, but immobile in soil
- Activator of many enzymes essential for photosynthesis & respiration, and to form starch and proteins; related to osmotic potential and turgor pressure
- Tissue levels related to crop load
- Adequate levels needed for firmness?

- K deficient plants have older leaves with necrotic lesions
- High soil K and low leaf %K often related to production problems

Magnesium (Mg)

Mg deficiency

- Mobile in plant, but immobile in soil

- Present in chlorophyll molecule, combines with ATP, activator of many enzymes essential for photosynthesis, respiration, and to form DNA and RNA
- Deficient plants have older leaves with interveinal necrosis or edges starting red and turning brown
- Deficiencies more common on sandy soil with low pH or if soil K is high

Sulfur (S)

S toxicity

- Moves with water in transpiration stream
- Required for protein synthesis
- Deficiency symptoms rare in blueberry due to use of fertilizers with sulfate
- Toxicity often reflected as "salt injury" (see photo)
- Uptake is not sensitive to soil pH

Calcium (Ca)

Ca deficiency

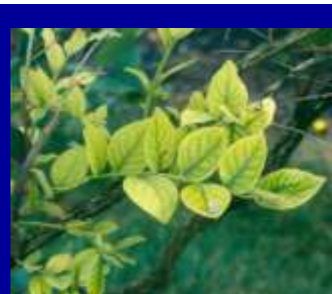
- Immobile in plant and soil; moves in xylem
- Required for cell division, to form cell walls, and normal membrane functions; Ca concentrations in cells are usually kept low by plant to prevent formation of salts; many enzymes are inhibited by high Ca in cells
- Deficiency symptoms in younger leaves; deformed, twisted tissues; low Ca may reduce fruit firmness
- Low soil moisture & cool, cloudy, humid conditions limit %Ca

Test Time!

- Your grandma has osteoporosis?
- Should you feed her lots of lettuce or lots of apples?
- Why?

1 cup fresh lettuce has ~ 10 mg Ca
1 cup fresh apple has ~ 7.5 mg Ca

Iron (Fe)



- Immobile in plant and soil
- Required for chlorophyll formation; forms part of enzymes and proteins
- Fe is internally precipitated in cells or formed into insoluble compounds
- Deficiency symptoms in younger leaves; interveinal chlorosis
- Fe is more available in soil at lower pH & may form insoluble precipitates with excess P

Manganese (Mn)

- Immobile in plant and soil
- More available at low pH
- Required for chlorophyll formation and activation of enzymes; may be involved in auxin regulation
- Deficiency symptoms in younger or older leaves depending on species; interveinal chlorosis
- Toxicity may occur in blueberry

Toxicity, blueberry

Boron (B)

- Very immobile in plant; mobile in soil
- Required for normal root tip elongation, cell division in shoot tip; required for normal elongation of pollen tubes
- Deficiency symptoms vary depending on plant species, but may reduce berry size (seed number) and bud break
- Toxicity can occur – tip burning of shoots

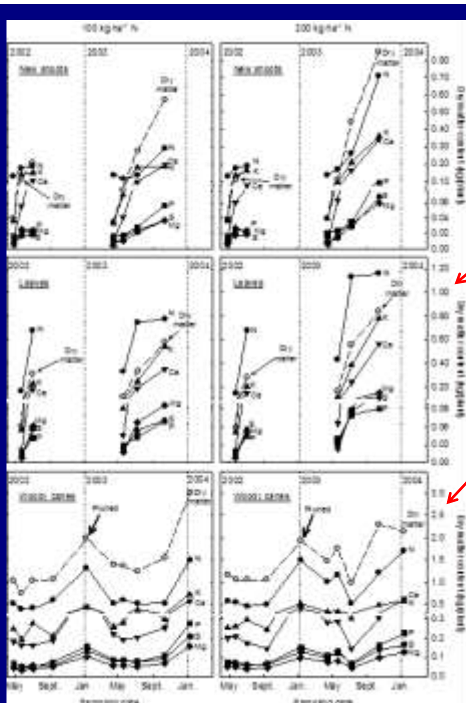
- Annual applications, without soil or tissue tests not recommended

Toxicity, grape

Zinc (Zn)

- Immobile in plant; very immobile in soil
- Required for chlorophyll synthesis and auxin production; required for function of many enzymes
- Deficiency symptoms include little leaf and rosette growth; leaf margins often distorted and leaves puckered; interveinal chlorosis often present
- Zn is more available at low pH

Nutrient content (g/plant)



Nutrient accumulation for the whole plant

New shoots & Leaves accumulate nutrients all season

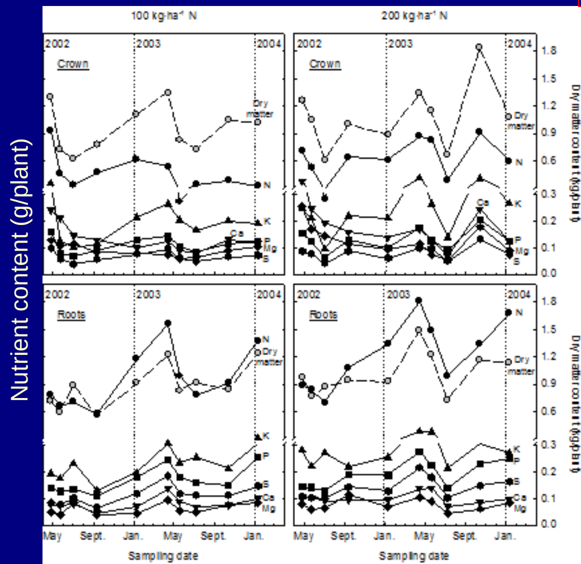
Nutrients are lost in leaves at senescence

Losses of N and K in woody tissue in early spring

Gains in macronutrients in late season

Nutrients lost with pruning

Nutrient accumulation for the whole plant



- Growth of crown and roots occurs in late summer (both) and spring (roots)
- Losses of N,P,K,Ca, Mg in crown in early spring, gains in late season
- Losses in roots in mid-summer, gains in fall-winter

Nutrients removed in fruit for 9 ton/acre yield. 'Bluecrop' as affected by N fertilization rate (avg. 2 years), machine harvest

Nitrogen Rate	Nutrient removed with 9 ton/acre yield (lb)					Nutrient removed per 9 ton/acre yield (g)				
(lb/a)	N	P	K	Ca	Mg	B	Fe	Mn	Cu	Zn
100	19	3	26	2	1	15	57	76	4	10
200	38	3	28	2	2	14	66	56	4	11

Soil & tissue testing are important to determine fertilizer needs

- Keep records of weather, plant health, fertilization, irrigation, and plant growth
- Adding more fertilizer will not compensate for other limiting factors
- Soil sampling should be representative, reflecting management unit
- Take soil test before planting
- Do soil analysis every 2 to 4 years
- Do annual tissue analysis (to compare to critical values and to establish trends)
- For diagnosis of problems or fixing problems, do both soil and tissue testing

Suggested soil nutrient deficiency levels

Nutrient	Unit	
pH (in water)	target:	4.5 to 5.5
		Deficient at less than:
Phosphorus (P; Bray)	ppm	25 to 50
Phosphorus (Olsen)	ppm	10
Potassium (K)	ppm	100 to 150
Calcium (Ca)	ppm	1000
Magnesium (Mg)	ppm	60
Manganese (Mn)	ppm	20
Boron (B)	ppm	0.5
		80
EC	dS/m	2

na=not available

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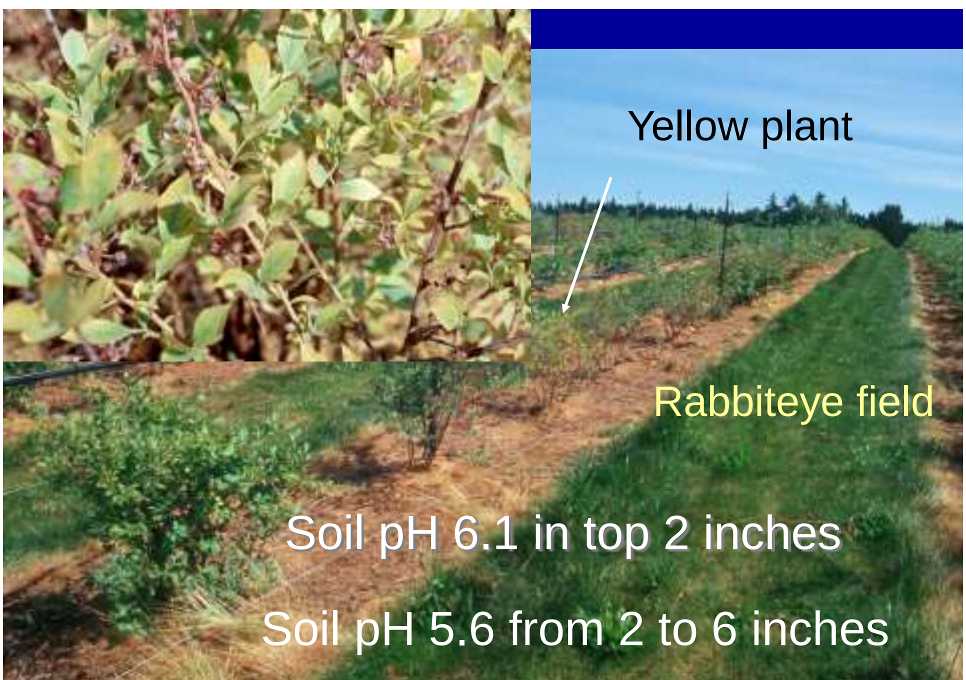
Why soil pH is important to blueberry production

- Blueberries grow best when the soil pH is between 4.5 and 5.5
- Soil pH is changed by cultural practices such as liming and N fertilizer, especially ammonium sulfate
- Blueberry plants don't grow well outside optimum pH range.

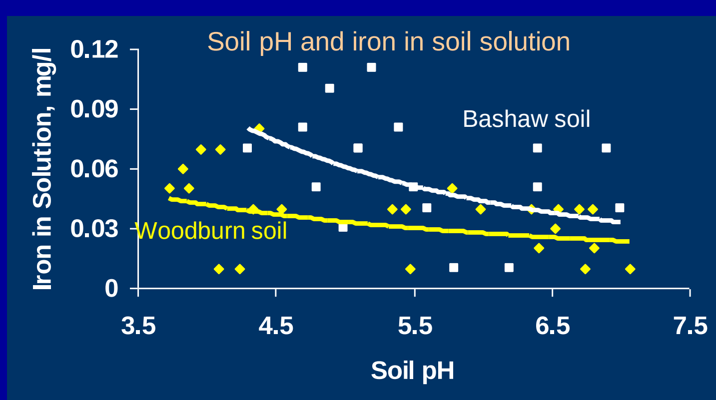


Lime induced iron deficiency

Rabbiteye   Highbush

Why do blueberries have iron deficiency?

- Iron availability decreases as the soil pH increases
- Blueberries seem to be inefficient at taking iron from soil with a pH above 5.5



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46ppm

Element	Expected Range
Fe	61 to 200 ppm

Leaves from the same plant

Soil pH influences the root environment by

- Controlling the solubility of toxic materials such as aluminum (Al) and manganese (Mn)
- Reducing the bacterial population that changes ammonium (NH_4^+) to nitrate (NO_3^-) as the soil pH declines. The NH_4^+ form of N has been shown as the only N form blueberries use
- Controlling the solubility/availability of nutrients.

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pH too low in established planting, Oregon

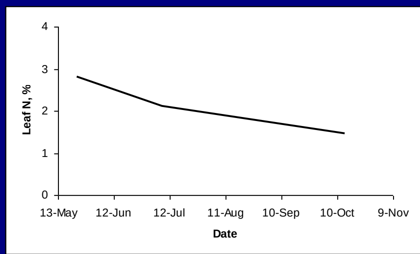
2007

High rates of N fertilizer will lower pH.
If pH is below 4.2 we see problems…..

Leaf Sampling Concepts

- Leaf concentrations depend on tissue type and tissue age
- Physiological age is more important than a calendar time
- There is no one perfect sample tissue or sample time for all elements
- Procedures used are a compromise
- Pick a procedure and stay with it
- Looking at long term trends is as important as critical values at a given time

Sample most recent fully-expanded leaves in late-July to early August in PNW



Bluecrop

'Elliott'
8-11-06

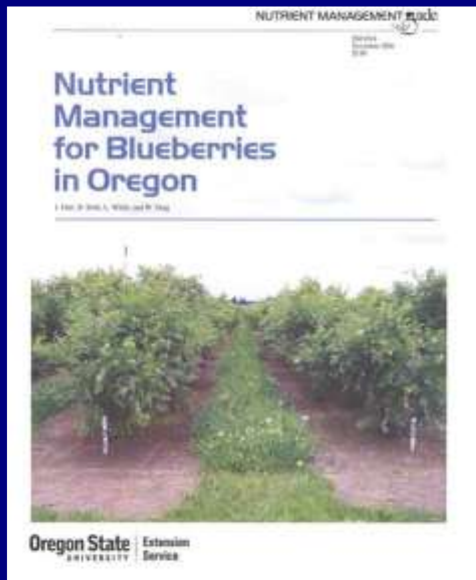
Table. Blueberry leaf N sufficiency, late July–mid August sampling

Leaf N (%)	**Status**
<1.50	deficient
1.51–1.75	below normal
1.76–2.00	normal
2.01–2.50	above normal
>2.50	excess

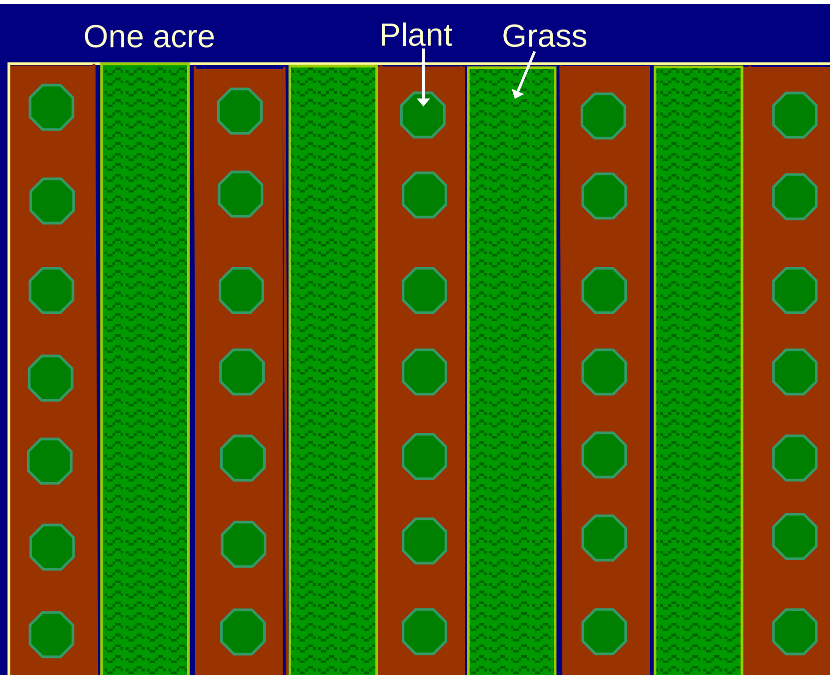
Suggested critical levels for leaf nutrient concentrations (most recent fully expanded leaves) – late July/early Aug; after harvest in PNW

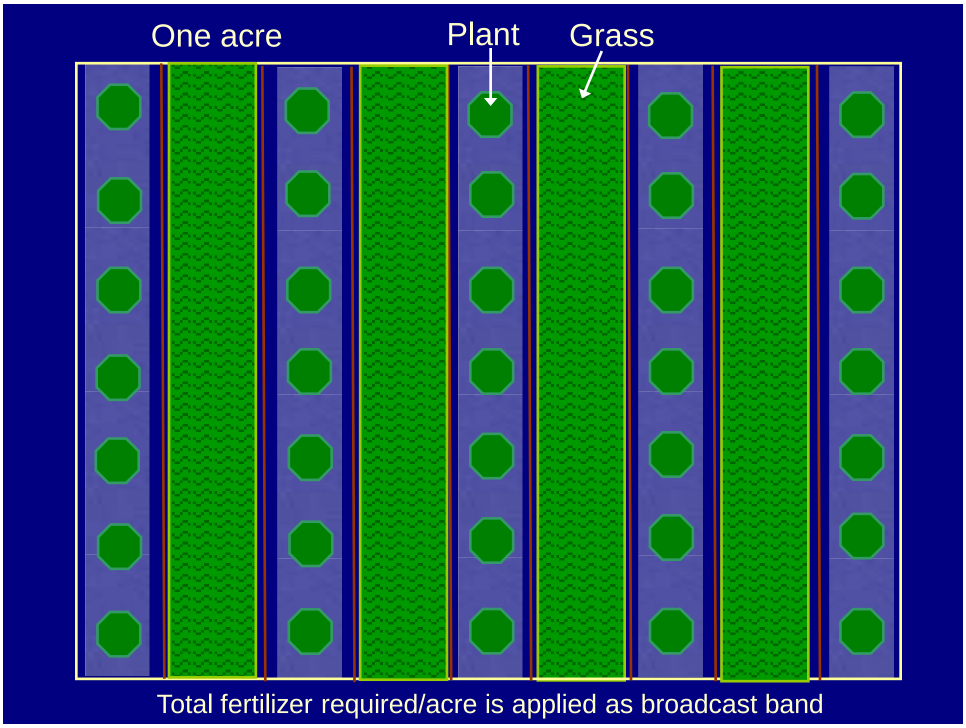
Nutrient	Deficient below			Sufficient			Excessive above		
	Northern	Southern	Rabbiteye	Northern	Southern	Rabbiteye	Northern	Southern	Rabbiteye
Nitrogen (%N)	1.7	1.7	1.7	1.76 to 2	1.8 to 2.1	1.2 to 1.7	2.5	2.5	2.5
Phosphorus (%P)	0.07	0.1	0.1	0.11 to 0.4	0.12 to 0.4	0.08 to 0.17	0.8	0.8	0.8
Potassium (%K)	0.2	0.3	0.3	0.41 to 0.7	0.35 to 0.65	0.28 to 0.60	0.95	0.95	0.95
Calcium (%Ca)	0.2	0.12	0.12	0.41 to 0.8	0.4 to 0.8	0.24 to 0.7	1	1	1
Magnesium (%Mg)	0.1	0.08	0.08	0.13 to 0.25	0.12 to 0.25	0.14 to 0.2	0.45	0.45	0.45
Sulfur (%S)	0.07	0.1	na	0.11 to 0.16	0.12 to 0.25	na	0.2	na	na
Manganese (ppm Mn)	10	23	23	31 to 350	50 to 350	25 to 100	450	450	450
Boron (ppm B)	20	20	20	31 to 80	30 to 70	12 to 35	150	200	200
Iron (ppm Fe)	50	60	60	61 to 200	60 to 200	25 to 70	400	400	400
Zinc (ppm Zn)	4	8	8	8 to 30	8 to 30	10 to 25	80	80	80
Copper (ppm Cu)	2	5	5	5 to 15	5 to 20	2 to 10	50	100	100

na=not available



http://extension.oregonstate.edu/catalog/





Can plants take up nutrients through leaves?

- Plants take up most nutrients through roots, but leaf uptake is possible
- Major limiting factor is how much fertilizer can be added to leaf surface before burning occurs
- It is almost impossible to supply a significant portion of the macronutrient needs of the plant with a foliar program – would require almost constant feeding with low concentrations
- Targeted micronutrient applications can supply a large portion of nutrient relative to plant demand
- For a nutrient to enter the leaf, it must penetrate the cuticle

Efficiency of uptake

- smaller molecules have better penetration
- waxy cuticle is major barrier to movement
- areas near veins, stomata, younger leaves have better penetration
- water stress can lead to thicker cuticles reducing penetration
- low relative humidity and rain reduce efficiency
- formulations important (chelates, buffers, surfactants…)
- every foliar application is a combo of foliar + ground

What about foliar "feeding"?

For N:
Maximum concentration is 5% urea in water (= 14 lb N/a)

In other perennial crops, maximum uptake through leaves + roots has been 50% (= 7 lb N/a)

Foliar applications are sometimes an effective method of correcting micronutrient deficiencies (specific or special situations)

Summary

- Understanding nutrient mobility is important
- Nutrients required are affected by plant age, canopy size, yield, time of year
- Fertilizer to apply depends on method of application and amount of nutrient needed
- Test for soil nutrient status (pH) and adjust if needed

Summary, Cont.

- Tissue testing is important to determine plant nutrient status
- Don't rely on standards for tissue testing at other times of year
- Goal is to ensure adequate nutrients are available when they are needed (e.g N for growth; Ca for fruit development and growth; K for fruit; P for root growth)
- Choose fertilizer formulations that are best for blueberry

Native *Vaccinium,* Lake Scott, Ore.