Foliar Elemental Analysis of Southern Highbush, Rabbit-eye, and Highbush Blueberries in the Southern United States

John R. Clark¹, David Creech², Max E. Austin³,
M.E. "Butch" Ferree⁴, Paul Lyrene⁵, Mike Mainland⁶,
Don Makus⁷, Liz Neuendorff⁸, Kim Patten⁹, and James M. Spiers¹⁰

Additional index words. *Vaccinium* spp., leaf nutrients

Summary. Highbush (*Vaccinium corymbosum* L.), rabbiteye (*V. ashei* Reade), and southern highbush (*Vaccinium* spp.) blueberries grown at seven locations in six southern states were sampled in 1988 and 1989 to determine foliar elemental levels among blueberry cultivars and types. Across locations, elemental levels of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and Al were similar for highbush and southern highbush types. Rabbiteye elemental levels were different from highbush and southern highbush for N, P, K, Ca, S, Mn, Cu, and Al. Rabbiteye blueberries appear to have different foliar levels, and may require species-specific standards for nutritional monitoring of plantings.

Blueberry growers use foliar analysis to monitor the nutritional status of plantings. A recommended time to collect blueberry leaf samples is following harvest because this is a time when elemental concentrations are at a period of least fluctuation (Ballinger, 1966; Clark et al., 1989). Mid-shoot leaves on shoots growing below the fruiting cluster commonly are collected (Eck, 1988).

Eck (1988) reviewed critical elemental levels for highbush and rabbiteye blueberries from leaf samples collected 1 to 3 weeks after harvest, and he indicated that differences in foliar levels existed between species for most elements analyzed. Clark (1988) compared rabbiteye and highbush foliar levels from samples collected in early August from plants growing on the same site in Arkansas, and found significant differences for N, P, Ca, Mg, Fe, Mn, Cu, and B. No difference was found for Zn, while K levels were not consistently different among cultivars of these species.

A recent development in blueberry cultivar improvement programs has been the southern or low-chill highbush blueberry. These cultivars have been developed by hybridizing standard highbush (*V. corymbosum*) clones with plants containing low-chill germplasm, primarily from *V. darrowi* Camp, along with *V. ashei* and southern forms of *V. corymbosum* (Lyrene, 1990). These cultivars are still predominantly *V. corymbosum*. 'Georgia-gem' contains 15% *V. darrowi* germplasm and 75% *V. corymbosum* (Austin and Draper, 1987), while 'O'Neal' is largely *V. corymbosum* germplasm, with genes from *V. darrowi*, *V. ashei*, and *V. angustifolium* Ait. (Ballington et al., 1990). The southern highbush blueberry industry is rather small, with

<200 ha reported in 1990 (Lyrene, 1990). However, due to the shorter bloom-to-ripening period of southern highbush as compared to rabbiteye cultivars, hectareage is expected to expand. No report has been made on elemental analysis of leaves of southern highbush cultivars.

This report provides foliar elemental analysis data collected from plantings established as a part of the Southern Cooperative Blueberry Germplasm Evaluation Program. The objective of this study was to use these cooperative plantings to compare foliar elemental levels of southern highbush, rabbiteye, and highbush blueberries grown at several locations throughout the southern United States. These data then could be used to assist in revealing what effect blueberry type has on foliar levels. This information might then be used in developing a set of foliar level standards for use in locations where one or more species or types of blueberries are grown.

Materials and methods

Seven plantings were used in this study, with locations at Booneville and Clarksville, Ark.; Gainesville, Fla.; Alapaha, Ga.; Poplarville, Miss.; Castle Hayne, N.C.; and Overton, Texas. Highbush, southern highbush, and rabbiteye cultivars planted in 1984 were represented at each location, although the number of locations for each cultivar was variable (Table 1). Foliar samples were collected in both 1988 and 1989 from three single-plant replications of each cultivar arranged in a randomized complete block in each planting and consisted of 20 mid-shoot leaves from fruiting canes. Samples were collected 2 to 4 weeks following final harvest at each location. Foliar samples were oven-dried at 70°C for 24 h, ground, and digested using a modified procedure of Blanchard et al. (1965). Samples were analyzed by inductively coupled plasma (ICP) (Instrumentation Laboratory, Lexington, Mass.) for P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and Al (Al in 1989 only). Nitrogen was analyzed by macro-Kjeldahl (Issac and Johnson, 1976). Samples of irrigation water were collected at each location in 1989 at the time of foliar sampling and analyzed for pH, conductivity, Na absorption ratio, Ca, Mg, Na, B, and bicarbonates. All foliar and water samples were analyzed by the Stephen F. Austin

¹Department of Horticulture and Forestry, PS 316, University of Arkansas, Fayetteville, AR 72701.

²Department of Agriculture, P.O. Box 13000, Stephen F. Austin State University, Nacogdoches, TX 75962.

³Department of Horticulture, Coastal Plain Experiment Station, Tifton, GA 31793-0748.

⁴University of Georgia, P.O. Box 1017, Fort Valley, GA 31030.

⁵Department of Horticultural Sciences, 2135 Fifield Hall, University of Florida, Gainesville, FL 32611.

⁶Horticultural Crops Research Station, 3800 Castle Hayne Road, Castle Hayne, NC 28429.

⁷USDA/ARS, South Central Family Farm Research Center, P.O. Box 144-A, Booneville, AR 72927. Present address: USDA/ARS/CPSR, Weslaco, TX 78596.

⁸Texas A&M Agricultural Research and Extension Center, Overton, TX 75684.

⁹Texas A&M Agricultural Research and Extension Center, Overton, TX 75684. Present address: Washington State University Research and Extension Center, Long Beach, WA 98631.

¹⁰USDA/ARS Small Fruit Research Station, Box 287, Poplarville, MS 38470.

Published with the approval of the Director, Arkansas Agricultural Experiment Station. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

Table 1. *Cultivars and number of samples collected for foliar analysis of southern highbush, rabbiteye, and highbush blueberry cultivars*

Cultivar	Type ^z	Total samples	No. years	No. locations
O'Neal	SH	39	2	7
Georgiagem	SH	36	2	6
NC-1524	SH	6	2	1
Cape Fear	SH	6	1	2
Tifblue	RE	39	2	7
Climax	RE	36	2	6
Premier	RE	3	1	1
Croatan	HB	39	2	7
Bluechip	HB	21	2	4

^zBlueberry types are: SH = southern highbush, RE = rabbiteye, and HB = highbush.

State Univ. Soil and Plant Tissue Testing Laboratory, Nacogdoches, Texas.

Soil samples were taken in June and Dec. 1988, and June 1989 from the row in which the plants used for foliar samples were growing. Samples were collected at 0–15-, 15–30-, and 30–45-cm depths. Samples collected in June 1988 were analyzed by the Soil and Plant Tissue Testing Laboratory, Univ. of Georgia, Athens. These samples were analyzed using Mehlich I extraction (Mehlich, 1953) and elemental analysis was by ICP spectroscopy. Samples from Dec. 1988 and June 1989 were analyzed by the Stephen F. Austin State Univ. Soil and Plant Tissue Testing Laboratory. For analysis of P, K, Ca, Mg, and S, Mehlich I extraction was used (Mehlich, 1953). Extraction of Fe, Mn, Zn, and Cu was by diethylenetriaminepentaacetic acid and triethanolamine (DTPA-TEA) (Lindsey and Norvell, 1978). All elemental determinations were done by ICP spectroscopy. Percent organic matter analysis of June 1988 samples was conducted using the Walkey-Black method (Jackson, 1958). Organic matter content of samples collected in Dec. 1988 and June 1989 was determined by organic matter loss on ignition, which involved drying the soil at 105C, followed by combustion at 440C. Percent organic matter was calculated by determining the loss of weight of soil from its initial weight at 105C to that following combustion at 440C. Soil pH was determined for all samples by soil water pH (Gaines and Mitchell, 1979).

Foliar analysis data were analyzed with the primary goal of determining if differences existed among blueberry types (highbush, southern highbush, and rabbiteye), with a secondary goal of determining differences among cultivars within type. Data were analyzed

by analysis of variance (ANOVA). Both locations and years were considered random factors because we wanted comparisons among types and cultivars to be applicable to the southern region. Cultivar was the only fixed source of variation. The random sources of variation within the model were location, replication within location, year within location, replication $\times$ year within location, location by cultivar, replication $\times$ cultivar within location, and cultivar $\times$ year within location. The residual source of variation was replication $\times$ cultivar $\times$ year within location. Least squares means and standard errors were obtained for each cultivar and then were averaged by blueberry type in order to compare types. Pairwise comparisons were made between types and between cultivars within type by a *t* test.

Results and discussion

The pH, conductivity, sodium absorption ratio, Ca, Mg, Na, B, and bicarbonates of irrigation water varied by location (Table 2). Soil chemical properties also varied widely (Table 3). The variations in water and soil analyses was expected due to the diversity of the locations. We consider this variation useful, because the intention

of the study was to determine foliar level variation among blueberry types over the southern region.

The ANOVA for the foliar elemental concentrations provided several major findings (Table 4). Location was the largest variance component for Mn and Al. Year within location was a significant variance component for all but Mn and Al, and contained the highest percentage of variation of all sources for five of 10 elements. The other common significant variance component was cultivar $\times$ year within location, which was significant for five of 10 elements, but was the largest variance component for Mg only.

Macroelement means revealed differences among blueberry type for all elements except Mg (Table 5). For N, P, K, Ca, and S levels, highbush and southern highbush were similar, whereas rabbiteye was significantly lower. Cultivar N levels within type were similar, with the exception of the rabbiteye cultivars—'Climax' had a lower N level than 'Tifblue'. Foliar P levels were slightly, but significantly, different among cultivars of southern highbush and highbush. Levels of K were different only among southern highbush cultivars, with 'Georgiagem' highest. Calcium levels were different only among rabbiteye cultivars—'Premier' was much higher than 'Tifblue' and 'Climax'. This may be due to the fact that 'Premier' was sampled at only one location in one year. Although Mg levels were similar among types, differences among cultivars within type were found for all three types. However, this again could be due to the small sample size for the two cultivars that show the greatest difference: 'Cape Fear' southern highbush (one location, 2 years) and 'Premier' rabbiteye (one location, 1 year). Levels of S

Table 2. *Irrigation water quality at seven blueberry germplasm evaluation sites*

Location	pH	Conductivity		Element ($\mu\text{g}\cdot\text{liter}^{-1}$)				Bicarbonates (meq/liter)
		($\text{S}\cdot\text{m}^{-1}$)	SAR ^z	Ca	Mg	Na	B	
Arkansas 1 ^y	7.0	8.6	0.0	7.4	3.4	2.5	0.0	0.68
Arkansas 2 ^x	6.2	3.2	0.0	1.6	0.7	2.0	0.0	0.12
Texas	7.2	8.6	0.0	6.6	4.4	3.7	0.0	0.61
Florida	8.0	29.9	0.0	60.1	13.7	6.8	0.01	4.04
Georgia	5.6	1.9	0.0	0.8	0.2	1.1	0.0	0.31
Mississippi	7.5	6.5	2.0	2.1	0.4	10.2	0.0	0.58
North Carolina	7.5	19.4	0.0	37.5	2.3	11.1	0.01	1.77

^zSodium absorption ratio.

^yArkansas 1 = Booneville.

^xArkansas 2 = Clarksville.

Table 3. *Soil analyses for seven blueberry germplasm evaluation sites, from samples taken at three depths. Data are based on pooling June 1988, Dec. 1988, and June 1989 soil samples.*

Location	pH	Organic matter (%)	Element (µg•g ⁻¹)										Conductivity (S•m ⁻¹)
			P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Al	
15-cm depth													
Arkansas 1 ^z	5.7	3.8	11	82	1599	90	45	69	88	1	0.7	112	101
Arkansas 2 ^y	5.9	3.2	10	107	1204	84	28	42	35	9	1.7	159	80
Texas	5.6	0.7	40	66	298	63	13	54	7	2	0.4	62	82
Florida	5.1	2.5	159	49	447	76	65	94	16	5	7.5	517	191
Georgia	5.4	1.9	37	70	496	70	24	55	5	3	0.2	170	98
Mississippi	4.8	2.3	69	212	430	71	39	128	248	1	0.5	225	202
North Carolina	3.8	24.7	86	128	970	115	32	91	3	6	0.2	985	222
15-30-cm depth													
Arkansas 1	5.7	2.7	7	60	1165	74	38	79	88	1	0.1	140	85
Arkansas 2	5.6	2.4	13	91	849	72	24	39	34	11	1.7	175	71
Texas	5.7	0.7	22	54	236	65	16	95	10	2	0.2	57	81
Florida	5.8	1.9	155	46	609	82	60	39	11	5	0.3	435	164
Georgia	6.1	1.6	20	35	730	82	30	25	3	1	0.1	173	113
Mississippi	5.0	2.0	32	136	483	102	49	43	235	1	0.3	267	155
North Carolina	3.9	10.2	63	34	512	61	20	54	1	3	0.1	980	121
30-45-cm depth													
Arkansas 1	5.4	2.5	6	61	1046	77	48	41	49	1	0.4	194	76
Arkansas 2	5.6	2.4	13	107	794	70	37	15	24	13	1.3	236	65
Texas	5.7	0.6	18	51	315	68	17	66	10	2	0.2	61	77
Florida	5.7	1.1	143	34	457	60	51	53	6	2	0.2	363	129
Georgia	6.1	1.0	11	23	401	63	27	22	1	1	0.2	120	104
Mississippi	5.2	1.6	12	94	599	134	78	17	157	1	0.2	206	128
North Carolina	4.1	3.9	33	12	280	36	14	84	2	2	0.1	755	91

^zArkansas 1 = Booneville.

^yArkansas 2 = Clarksville.

showed only slight variation between highbush and southern highbush, although significant differences among rabbiteye cultivars were found.

There were significant differences in Fe, Mn, Cu, and Al levels among types, but Zn levels were similar (Table 6). Rabbiteye Fe level was lower than that for highbush, although not different from southern highbush. Standard errors for Fe means were rather large, explaining the lack of statistical differences among numerically large differences of means. This is especially notable with the large numerical differences of Fe means for rabbiteye cultivars. Mn levels were similar for high-

bush and southern highbush, but much lower for rabbiteye. 'Premier' Mn level was approximately three times that of the other rabbiteye cultivars, although this is probably due to the small sample size for this cultivar. Cu level was slightly lower for rabbiteye and similar for highbush and southern highbush. Cultivar differences were found among southern highbush, with 'O'Neal' having the highest Cu level. Al level for rabbiteye was much lower compared to highbush or southern highbush. Cultivar differences for Al were found among highbush cultivars only.

The results reported here parallel those of Clark (1988), who found

differences in N, P, Ca, Fe, Mn, and C between highbush and rabbiteye cultivars. The data presented here differ from those of Clark, in that K levels were similar between one highbush and two rabbiteye cultivars in his study, whereas differences among types were found in our study. Levels of Mg were similar among types in this report, but Clark found lower Mg levels for rabbiteye cultivars. Data presented in this report correspond to Eck's (1988) comparison of rabbiteye and highbush foliar levels. Fruit of highbush grown at Booneville, Ark., were reported to have higher protein-N, P, Ca, Mg, Fe, Cu, and B compared to rabbiteye grown at the same location (Makus and Morris, 1993).

Our objective was to compare foliar elemental levels of these three blueberry types, and determine if differences in foliar level existed at a specific time. A major reason for determining if differences exist was to provide information for more-precise nutritional monitoring of blueberry plantings through foliar analysis. It has been observed that plant analysis laboratories have used highbush foliar standard values for determining nutritional

Table 4. *Percentage of variation by source in the analysis of variance of elemental concentration data from southern highbush, rabbiteye, and highbush blueberry leaves.*

Variance component	Element									
	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Al ^z
Location	25	10	8	18	0	39	10	40**	0	68**
Year (L)	48**	51**	30**	29**	36**	49**	32**	4	63**	---
L × Cv	2	8*	6	5	4	0	12*	9	2	6
Cv × Y(L)	5*	3	17*	21**	38**	2	3	10*	0	---
Residual ^y	20	28	39	27	22	10	43	37	35	36

^zAl data collected in 1989 only.

^yResidual is the sum of all components involving replication.

***F test statistically significant at $P \leq 0.05$ and 0.01 , respectively.

Table 5. *Macroelement concentrations expressed as percent and standard error from foliar analysis of sampled southern highbush, rabbiteye, and highbush cultivars*

Type/ cultivar	Element											
	N		P		K		Ca		Mg		S	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Southern highbush												
O'Neal	1.53 a ^z	0.10	0.10 ab	0.007	0.52 b	0.05	0.64 a	0.06	0.17 b	0.02	0.17 a	0.03
Georgiagem	1.51 a	0.10	0.09 b	0.007	0.72 a	0.06	0.62 a	0.06	0.15 c	0.02	0.15 a	0.03
NC-1524	1.44 a	0.14	0.10 ab	0.012	0.44 b	0.11	0.62 a	0.11	0.15 c	0.05	0.15 a	0.03
Cape Fear	1.65 a	0.13	0.11 a	0.010	0.50 b	0.10	0.73 a	0.10	0.27 a	0.04	0.15 a	0.03
Rabbiteye												
Tifblue	1.24 a	0.10	0.09 a	0.007	0.36 a	0.05	0.35 b	0.06	0.14 b	0.02	0.14 a	0.03
Climax	1.08 b	0.10	0.08 a	0.007	0.42 a	0.06	0.31 b	0.06	0.13 b	0.02	0.12 b	0.03
Premier	1.16 ab	0.16	0.07 a	0.014	0.30 a	0.14	0.74 a	0.14	0.22 a	0.06	0.13 ab	0.04
Highbush												
Croatan	1.43 a	0.10	0.10 a	0.007	0.50 a	0.05	0.57 a	0.06	0.17 b	0.02	0.15 a	0.03
Bluechip	1.46 a	0.10	0.11 b	0.008	0.47 a	0.06	0.64 a	0.07	0.22 a	0.03	0.14 a	0.03
Type												
Southern highbush	1.53 a	0.10	0.10 a	0.007	0.55 a	0.05	0.65 a	0.06	0.18 a	0.02	0.15 a	0.03
Rabbiteye	1.16 b	0.10	0.08 b	0.007	0.36 b	0.06	0.47 b	0.07	0.16 a	0.02	0.13 b	0.03
Highbush	1.44 a	0.10	0.11 a	0.007	0.49 a	0.05	0.60 a	0.06	0.20 a	0.02	0.15 a	0.03

^zMeans not followed by the same letter among cultivars within type and between types are significantly different at $P \leq 0.05$, as determined by a t test.

status of non-highbush plantings, especially rabbiteye plantings. Our data reveal that foliar analysis differences between highbush and rabbiteye types were found, and these findings should be useful in determining the nutritional status of plantings that are sampled 2 to 4 weeks following harvest. Our findings should be useful in states where production of highbush types and rabbiteye cultivars occur. A different set of critical values may be required for making appropriate recommendations for rabbiteye nutri-

tional management based on foliar analysis.

However, it must be emphasized that other factors have been found to affect elemental content of blueberry leaves. Crop load has been reported to affect N and K levels in leaves (Ballinger, 1966; Ballinger and Kushman, 1966; Ballinger et al., 1963; Eck, 1983). Ballinger (1966) indicated that, regardless of the time of foliar sampling, crop load must be considered in using foliar sampling as a tool for nutritional monitoring of blueberry plantings. The

plants sampled in our study fruited in the year of sampling, but no data were collected to relate crop load to foliar elemental level. Therefore, crop load effects could have affected foliar levels differently at different locations. However, one would assume that differences in foliar levels among blueberry types might be parallel within location.

Further research on blueberry type response to different fertilizer rates will be required to fully clarify if different blueberry types have different op-

Table 6. *Microelement concentrations expressed as micrograms per gram and standard error from foliar analysis of sampled southern highbush, rabbiteye, and highbush cultivars*

Type/ cultivar	Element									
	Fe		Mn		Zn		Cu		Al ^z	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Southern highbush										
O'Neal	97 a ^y	19.0	237 a	48.5	116 a	2.0	11 a	1.4	124 a	28.5
Georgiagem	99 a	19.5	239 a	19.8	15 a	2.1	6 b	1.4	127 a	28.5
NC-1524	97 a	37.2	186 b	88.1	12 a	4.8	8 ab	2.1	120 a	40.9
Cape Fear	96 a	32.3	253 a	76.6	16 a	4.1	9 ab	2.0	---	---
Rabbiteye										
Tifblue	83 a	19.0	54 a	48.5	14 a	2.0	6 a	1.4	82 a	28.5
Climax	49 a	19.5	43 a	49.8	13 a	2.1	6 a	1.4	62 a	28.5
Premier	74 a	43.7	147 a	102.1	13 a	5.8	7 a	2.5	---	---
Highbush										
Croatan	93 a	19.0	215 a	48.5	14 a	2.0	8 a	1.3	120 b	28.5
Bluechip	119 a	21.8	254 a	54.5	14 a	2.5	8 a	1.5	159 a	30.2
Type										
Southern highbush	97 ab	18.6	229 a	47.8	15 a	2.0	8 a	1.3	124 a	28.5
Rabbiteye	69 b	20.7	81 b	51.8	13 a	2.3	6 b	1.4	72 b	27.2
Highbush	106 a	17.7	234 a	45.9	14 a	1.8	8 a	1.3	140 a	27.7

^zAl analyzed in 1989 only.

^yMeans not followed by the same letter between cultivars within type and between types are significantly different at $P \leq 0.05$ by a t test.

timum foliar levels. Also, because highbush and rabbiteye types often differ in plant size, with rabbiteye being larger, simple dilution of the nutrients may be the basis for the foliar differences.

New cultivars of southern highbush blueberries are under development, and these may have different genetic backgrounds than those used in this study. When the more-diverse blueberry germplasm is included in the parentage of these new cultivars, the use of standard highbush foliar levels may not be appropriate for nutritional monitoring and fertilizer recommendations.

Conclusion

In a comparison of foliar elemental levels among highbush, southern highbush, and rabbiteye blueberries grown at seven locations in six southern states, it was found that N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and Al levels were similar for highbush and southern highbush types, but rabbiteye levels were different from those types for N, P, K, Ca, S, Mn, Cu, and Al levels. These differences should be noted by individuals evaluating the nutritional status of blueberry plantings using foliar analysis in states where several types are grown. Because rabbiteye levels appear to be different for several elements, these differences must be considered when making fertility management recommendations for one or more elements. However,

other factors, such as crop load, time of sampling, or fertilizer rate, must be considered when using foliar analysis for fertility recommendations.

Acknowledgement

We thank Ron McNew, Coordinator and Professor, Univ. of Arkansas Agricultural Statistics Laboratory, for his analysis of the data in this report.

Literature Cited

- Austin, M.E. and A.D. Draper. 1987. 'Georgiagem' blueberry. HortScience 22:682-683.
- Ballinger, W.E. 1966. Seasonal trends in 'Wolcott' blueberry (*Vaccinium corymbosum* L.) leaf and berry composition. N.C. Agr. Expt. Sta. Tech. Bul. 173.
- Ballinger, W.E. and L.J. Kushman. 1966. Factors affecting the mineral-element content of leaves and fruit of Wolcott blueberries. Proc. Amer. Soc. Hort. Sci. 88:325-330.
- Ballinger, W.E., L.J. Kushman, and J.F. Brooks. 1963. Influence of crop load and nitrogen applications upon yield and fruit qualities of Wolcott blueberries. Proc. Amer. Soc. Hort. Sci. 82:264-275.
- Ballington, J.R., C.M. Mainland, S.D. Duke, A.P. Draper, and G.J. Galletta. 1990. 'O'Neal' southern highbush blueberry. HortScience 25:711-712.
- Blanchard, R.W., G. Rhem, and G.C. Caldwell. 1965. Sulfur in plant materials by digestion with nitric and perchloric acid. Soil Sci. Soc. Amer. Proc. 29:71-72.
- Clark, J.R. 1988. Comparison of elemental content of leaves from highbush and rabbiteye blueberries. Ark. Farm Res. 37 (3):12.
- Clark, J.R., D.G. Dombek, and D.B. Marx. 1989. Seasonal variation in elemental content of 'Bluecrop' blueberry leaves. Ark. Agr. Expt. Sta. Bul. 920.
- Eck, P. 1983. Optimum potassium nutritional level for production of highbush blueberry. J. Amer. Soc. Hort. Sci. 108:520-522.
- Eck, P. 1988. Blueberry science. Rutgers University Press, New Brunswick, N.J.
- Gaines, T.P. and G.A. Mitchell. 1979. Chemical methods for soil and plant analysis. Univ. of Georgia Coastal Plain Expt. Sta. Agron. Hdbk. 1.
- Issac, R.A. and W.C. Johnson. 1976. Determination of total nitrogen in plant tissue, using a block digester. J. AOAC 59: 98-100.
- Jackson, M.L. 1958. Soil chemical analysis. Prentice-Hall, Englewood Cliffs, N.J.
- Lindsey, W.L. and W.A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Amer. J. 42:421-428.
- Lyrene, P.M. 1990. Low-chill highbush blueberries. Fruit Var. J. 44:82-86.
- Makus, D.J. and J.R. Morris. 1993. A comparison of fruit of highbush and rabbiteye cultivars. J. Food Qual. 16:417-428.
- Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, and NH_4 . North Carolina Soil Test Div. Mimeo.