Dry Matter, Nitrogen, Potassium and Phosphorus Partitioning in Blueberry Plants during Winter

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Abstract

Mature blueberry plants cvs. 'Elliott', 'O'Neal', 'Bluejay', 'Brigitta' (*Vaccinium corymbosum* L.) and 'Brightwell' (*Vaccinium ashei* Reade) were destructively harvested during mid-winter 2001 from a commercial orchard in Gorbea, Chile (38^o latitude S). Plants were divided into parts and analyzed for dry weight (DW), nitrogen (N), potassium (K) and phosphorous (P) concentration and partitioning. The crown had the largest DW in the plant (27 to 36 %), followed by roots and 4-year-old wood. Nitrogen, P and K concentrations varied amongst plant parts. In all five cultivars the highest N, P and K concentration were found in floral buds (2.8% N, 0.3 %P and 0.8 %K for 'Brightwell'). As tissue aged, N, P and K concentration declined to 0.45 %N, 0.04% P and 0.15%K in 4-year-old wood 'Brightwell'. Total N, P and K partitioning in the plant was significantly correlated to plant part dry weight. Crown and roots were the largest N, P and K storage organs during winter in all cultivars. It is speculated that tissues with the highest nutrient concentration, such as buds, may be very important in supporting new growth.

INTRODUCTION

The role of over winter storage reserves to support early spring growth have been well documented in many deciduous fruit trees. Nitrogen and carbohydrate reserves have been the main focus of research, since they play a key role in the spring before newly applied fertilizer is absorbed by the plant and net photosynthesis occurs. Biomass and nitrogen (N) partitioning have been studied in blueberry during different fazes of the growing season. Total plant biomass increased through the season with the most rapid accumulation in July and little change between August and October (Throop and Hanson, 1997). Dry matter partitioning in blueberry changed during the season and was affected by pruning (Strik et al., 2003), nitrogen fertilization (Merhaut and Darnell, 1996), and photoperiod (Spann et al., 2004). In other species, dry weight partitioning has also been affected by planting system (Caruso, et al., 1999)

Total N in the plant changes during the season; the lowest values occur in May, total N increases until early August and then stays constant until September (Throop and Hanson, 1997). Plant density per hectare affects the total biomass accumulation per plant; plants spaced at a narrower distance in-the row are smaller than those at a wider space (Strik and Buller, 2004). Roots of fruit tree species have been recognized as the main storage organ for N reserves (Taylor, 1967).

No report has been published to date on potassium or phosphorus partitioning in blueberry in winter. The objective of this study was to determine biomass partitioning and the main storage organs of nitrogen, potassium and phosphorus during winter in different blueberry cultivars.

MATERIAL AND METHODS

Mature eight to ten-year old blueberry plants cvs. 'Elliott', 'O'Neal', 'Bluejay', 'Brigitta' (*Vaccinium corymbosum* L.) and 'Brightwell' (*Vaccinium ashei*) were destructively harvested during mid-winter in July 2001 from a commercial orchard in Gorbea, Chile (38^o latitude S) before pruning. Four plants of each cultivar were randomly

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chosen from the field, dug out up to a 0.7 m depth and divided into parts: vegetative buds, floral buds, 1-year-old, 2-year-old, 3-year-old, 4-year and older wood, crown, and roots. Plant parts were dried at 65°C to constant weight and total dry weight (DW) measured (g). A sub-sample of each part was sent for analysis of nitrogen (%), potassium (%) and phosphorous (%). Partitioning of biomass and total nutrient content per plant were calculated as the product of N, P or K concentration of each organ times their dry weight.

RESULTS AND DISCUSSION

Nutrient Concentration

Nitrogen (%), P (%) and K (%) varied amongst plant parts ($p< 0.001$). Flower buds had the highest nutrient concentration in the plant in all cultivars, followed by 1-year-wood and fine roots (Table 1). The highest N concentration in all the cultivars was found in flower buds (2.9% in 'Brightwell' to 1.7% in 'Elliott') followed by vegetative buds, one-year-old wood and roots. As expected, younger organs had a higher N concentration than older organs. The lowest concentration of all nutrients was found in 4-year- and older wood. Phosphorous and K concentration followed the same trend as N: higher concentration in younger tissues compared to older ones (Table 1). Potassium concentration was highest in buds (0.4 to 0.8% depending on cultivar) and lowest in 4-year-old wood (0.2%). Differences were found in concentration amongst cultivars; 'Brightwell' had a higher concentration of N, P, and K in young organs.

Buds were also the most P concentrated tissue in the plant with up to 0.3% in 'Brightwell'.

Nutritional standards have been developing for leaf analysis during the growing season (Strik et al., 1993). However standards for nutrient concentration in winter are not available. It is speculated that higher concentrations of N, P and K in buds may affect the quality of flowers and the initial fruit growth. Larger buds with higher nutrient concentration may produce larger fruits. Maust et al., (2000) found a positive correlation between carbohydrate reserves in canes and initial vegetative and fruit growth in Southern Highbush blueberry. This relationship was not measured in this study.

Biomass and Nutrient Partitioning

Total plant biomass differed amongst cultivars ($p=0.005$) and organ ($p< 0.001$). 'O'Neal' and 'Bluejay' had the largest biomass per plant, and 'Brightwell' the lowest, although they were all 10-year-old bushes (Table 1). Differences amongst cultivar can be explained by plant vigor and probably cultural practices. In all cases (except in 'Bluejay') the crown was the largest organ in the plant (26 to 36% of the DW), followed by roots (15 to 25%) and 4-year-old wood (14 to 42 %) (Table 2). These proportions change in young plants and is also affected by in-row spacing (Strik and Buller, 2004). In this case all plants were the same age and planted at 1.5 m (in-row) by 3 m between rows, so differences were probably due to plant vigor. 'Bluejay' had a large percent of DW in older tissues, perhaps an indicator of plant aging. In 'Bluejay' there might be a need to rejuvenate the plant with heavier pruning to increase the proportion of younger productive wood. These plants have been lightly pruned during its lifetime, which is probably one of the main reason of this type of distribution of wood ages. [

Roots accounted for 15 to 27% of the total plant DW. Biomass in 1-year-wood ranged from 1.9% in 'Bluejay' to 10% in 'Brightwell'. Since blueberry bear fruit on 1-year-old wood, the proportion of this wood age may be related to future fruit quantity in the plant; this was not measured in this study.

The ideal biomass partitioning amongst parts has not been established in blueberry and it might vary with plant density and cultivar. However a larger proportion of younger wood is probably desirable to achieve high fruit production per hectare.

Twenty to 33% of total N in the plant in winter was found in roots and about the same percentage in the crown, with some variation depending on cultivar. These two organs are the main N storage tissues in the plant during winter. In young 2-year-old peaches 60 to

80% of the total N in the plant during winter was found in roots (Taylor and May, 1967), suggesting that plant age may have an effect on N partitioning. Potassium was stored mainly in the crown (25 to 32%) and in roots. In ‘Bluejay’, 42% of K was found in 4-year-old wood. Phosphorous was found mainly in roots (22 to 46%) and in the crown (19 to 27%). In ‘Bluejay’, 27% of the P in the plant was found in 4-year-wood. Partitioning was driven mainly by total biomass rather than concentration.

According to these results the main nitrogen, potassium and phosphorus storage organs in blueberry during winter are the crown, roots, and old wood. These results however maybe be biased as these organs also have the largest biomass. It is unknown what percentage of their total nutrient content can be exported to other organs to support the new spring growth. Maybe organs with a higher nutrient concentration like buds will have a very important role supporting new growth since they have a larger nutrient export capacity than older organs. This hypothesis needs to be tested.

CONCLUSIONS

- Although the 5 cultivars differed in absolute N, P, and K concentration, they showed similar patterns in nutrient concentration amongst tissues. Flower buds had the highest N, P and K concentration and 4-year-old wood the least.
- Total plant biomass and partitioning differed amongst cultivars, but a large percentage was found in old wood due probably to the age of the plants. ‘Bluejay’ had 42% of its DW in 4-year-old wood and only 2% in 1-year wood. ‘Brightwell’ had a more uniform distribution of biomass across wood ages.
- N, P and K partitioning in the plant was dependent on part biomass.
- The relative proportion of new to old wood may serve as an indication of the aging status of a plant or orchard. More severe pruning to renew wood may be necessary in ‘Bluejay’.
- The main N, P and K storage organs in blueberry during winter were crown and roots, however the export capacity of this nutrient is unknown.

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Tables

Table 1. Nitrogen (N%), potassium (K%) and phosphorous (P%) concentration in different plant parts of mature blueberry cultivars during mid-winter. Gorbea, Chile 2001.

Plant Part	Bluejay			Brigitta			Brightwell			Elliott			O'Neal		
	N (%)	K (%)	P (%)	N (%)	K (%)	P (%)	N (%)	K (%)	P (%)	N (%)	K (%)	P (%)	N (%)	K (%)	P (%)
Flower bud	2.6	0.64	0.24	1.8	0.52	0.19	2.9	0.84	0.32	1.7	0.38	0.18	2.7	0.85	0.26
Vegetative bud	2.0	0.36	0.16	1.5	0.23	0.12	2.2	0.69	0.23	1.7	0.25	0.14	2.0	0.47	0.18
1-year-old	1.0	0.30	0.09	0.7	0.29	0.07	1.0	0.50	0.09	0.9	0.37	0.07	0.9	0.36	0.07
2-year-old	1.0	0.25	0.07	0.6	0.24	0.05	0.6	0.28	0.05	0.9	0.33	0.06	0.9	0.30	0.06
3-year-old	0.7	0.19	0.05	0.6	0.18	0.04	0.5	0.25	0.04	0.7	0.23	0.05	0.7	0.19	0.05
4-year-old and older	0.6	0.19	0.04	0.5	0.17	0.04	0.5	0.15	0.04	0.6	0.18	0.05	0.7	0.15	0.05
Crown	0.7	0.19	0.05	0.6	0.18	0.04	0.5	0.25	0.04	0.7	0.23	0.05	0.7	0.19	0.05
Roots	1.2	0.20	0.12	1.2	0.21	0.09	0.7	0.28	0.07	1.0	0.24	0.12	1.6	0.19	0.20
Significance	***	***	**	***	***	**	***	***	**	***	**	**	***	***	**

*** p-value < 0.001

** p-value < 0.005

Table 2. Dry weight (g) and percent dry weight partitioning in different plant parts of mature blueberry cultivars during mid-winter.

Plant organ	Bluejay		Brigitta		Brightwell		Elliott		O' Neal	
	DW (g)	% of total	DW (g)	% of total	DW (g)	% of total	DW (g)	% of total	DW (g)	% of total
Flower bud	10.2	0.15	25.3	0.33	8.6	0.56	16.4	0.44	42.5	0.49
Vegetative Bud	0.9	0.01	6.0	0.08	2.7	0.18	2.0	0.05	9.6	0.11
1-year	127.6	1.89	450.3	5.94	162.0	10.53	247.6	6.73	551.2	6.40
2-year-old	198.4	2.94	722.6	9.53	206.8	13.44	269.2	7.32	658.9	7.65
3-year-old	223.0	3.30	614.0	8.10	224.4	14.59	537.0	14.59	882.3	10.25
4-year and older	2815.6	41.68	1533.9	20.24	258.0	16.77	487.9	13.26	2097.4	24.36
Crown	1833.7	27.15	2665.1	35.16	440.3	28.62	1116.0	30.33	2758.6	32.04
Roots	1545.6	22.88	1562.4	20.61	235.5	15.31	1004.0	27.28	1602.7	18.61
Total Plant	6755.0	100	7579.6	100	1538.2	100	3680.1	100	8610.4	100

Table 3. Nitrogen content (mg) and percent nitrogen partitioning in different plant parts of mature blueberry cultivars during mid-winter.

Organ	Bluejay		Brigitta		Brightwell		Elliott		O' Neal	
	N (mg)	% of total	N (mg)	% of total	N (mg)	% of total	N (mg)	% of total	N (mg)	% of total
Flower bud	265	0.5	450	0.9	249	2.6	270	0.9	1114	1.4
Vegetative bud	18	0.0	90	0.2	60	0.6	33	0.1	199	0.3
1-year-old	1426	2.8	3465	6.8	1658	17.0	2104	7.2	5895	7.7
2-year-old	1818	3.5	4416	8.7	1211	12.4	2277	7.8	6011	7.8
3-year-old	1486	2.9	3532	7.0	1166	12.0	3809	13.0	6143	8.0
4-year and older	17961	34.7	7648	15.1	1147	11.8	3145	10.8	14303	18.6
Crown	12053	23.3	15335	30.2	2295	23.5	8039	27.5	18722	24.4
Roots	16716	32.3	15810	31.2	1958	20.1	9566	32.7	24187	31.5
Total plant	51742	100	50747	100	9744	100	29243	100	76821	100

Table 4. Phosphorous (mg) and percent phosphorous partitioning in different plant parts of mature blueberry cultivars during mid-winter.

	Bluejay		Brigitta		Brightwell		Elliott		O' Neal	
Organ	P (mg)	% of total	P (mg)	% of total	P (mg)	% of total	P (mg)	% of total	P (mg)	% of total
Flower bud	24.6	0.6	48.8	1.2	27.3	3.3	29.4	1.1	108.2	1.6
Vegetative bud	1.4	0.0	7.4	0.2	6.4	0.8	2.7	0.1	18.3	0.3
1-year-old	116.0	2.6	316.1	7.8	141.9	17.0	181.5	7.0	466.2	7.0
2-year-old	121.8	2.8	354.9	8.8	100.9	12.1	162.6	6.2	405.9	6.1
3-year-old	100.8	2.3	257.0	6.3	90.4	10.8	256.0	9.8	413.5	6.2
4-year and older	1201.0	27.2	628.0	15.5	105.0	12.6	233.9	9.0	969.1	14.5
Crown	842.0	19.1	1106.5	27.3	176.2	21.1	538.8	20.6	1276.2	19.1
Roots	2004.6	45.4	1330.7	32.9	185.5	22.2	1205.4	46.2	3012.5	45.0
Total plant	4412.2	100	4049.3	100	833.7	100	2610.3	100	6690.6	100

Table 5. Potassium (mg) and percent potassium partitioning in different plant parts of mature blueberry cultivars during mid-winter.

	Bluejay		Brigitta		Brightwell		Elliott		O' Neal	
Organ	K (mg)	% of total	K (mg)	% of total	K (mg)	% of total	K (mg)	% of total	K (mg)	% of total
Flower bud	67	0.5	130	0.9	72	1.7	63	0.7	360	2.0
Vegetative bud	3	0.0	14	0.1	19	0.5	5	0.1	51	0.3
1-year-old	417	3.3	1416	9.6	771	18.5	871	9.9	2015	11.5
2-year-old	471	3.7	1729	11.7	572	13.7	852	9.7	1940	11.0
3-year-old	425	3.3	1091	7.4	561	13.4	1236	14.0	1737	9.9
4-year and older	5311	41.5	2511	17.0	396	9.5	860	9.7	3091	17.6
Crown	3552	27.8	4793	32.5	1101	26.4	2563	29.0	5267	30.0
Roots	2536	19.8	3085	20.9	685	16.4	2375	26.9	3020	17.2
Total plant	13200	100	16185	100	4947	100	9696	100	19495	100