Blueberry survey Report

Massimo Iorizzo, Plants for Human Health Institute, North Carolina State University, NC

R. Karina Gallardo, School of Economic Sciences, Washington State University, WA

Parichat Klingthong, School of Economic Sciences, Washington State University, WA

Qi Zhang, School of Economic Sciences, Washington State University, WA

James Polashock, USDA-ARS, NJ

Cesar Rodriguez-Soana, P.E. Marucci Blueberry and Cranberry Research and Extension Center, Rutgers University, NJ

Nicholi Vorsa, P.E. Marucci Blueberry and Cranberry Research and Extension Center Rutgers University, NJ

Michael Dossett, BC Berry Cultivar Development Inc., Agassiz Research and Development Centre, BC, Canada

Patrick P. Edger, Department of Horticulture, Michigan State University, MI

Harald Scherm, Department of Plant Pathology, University of Georgia, GA

Hamid Ashrafi, Department of Horticultural Science, North Carolina State University, NC

Ebrahiem Babiker, Thad Cochran Southern Horticultural Laboratory, USDA-ARS, MS

Chad E. Finn, USDA-ARS, Horticultural Crops Unit, OR

We gratefully acknowledge the contributions of the following collaborators and supporting institutions:

the following institutions, their directory boards and members who provided letters of support for the USDA-SCRI planning grant that funded this project and for participating in the survey: (1) Massachusetts Cultivated Blueberry Growers Association; (2) Washington Blueberry Commission; (3) Georgia Blueberry Growers Association; (4) Florida Blueberry Growers Association; (5) Oregon Blueberry Commission; (6) Lower Mainland Horticulture Improvement Association; (7) North Carolina Blueberry Council; (8) Gulf South Blueberry Growers Association; (9) New Jersey Blueberry and Cranberry Research; (10) British Columbia Blueberry Council; (11) Berry Blue; (12) California Blueberry Commission; (13) Dole Nutrition Institute; (14) Driscoll; (15) Fall Creek Farm & Nursery, Inc.; (16) North America Blueberry Council

The following collaborators for their contribution in developing the blueberry survey: Nahla Bassil, William O. Cline, Kim Hummer, Changying Li, Mary Ann Lila, Penelope Perkins-Veazie, Lisa J. Rowland; Megan Bame, Hamed Bostan, and Yunyang Zhao.

The following meeting organizers for coordinating with project collaborators to distribute and present the project and the survey at growers association meetings: Gary Pavlis, Renee Allen, Yang Wei Qiang, Jeffrey G. Williamson, William O. Cline, and Bill Baisley.

More information about the Vaccinium planning project can be found at Vaccinium web page:

https://pgnglab.plantsforhumanhealth.ncsu.edu/vaccinium-project/

Summary report.

This report summarize the results of the blueberry breeding trait survey that was distributed at 10 blueberry grower association meetings between November 2016 and March 2017 in nine U.S. states and one Canadian province. This study emerged from a U.S. Department of Agriculture-funded planning grant titled “Research and extension initiative for cranberry and blueberry: Current and future needs”. The objectives of this project are to: 1) establish the first blueberry and cranberry multi-state breeding and extension research initiative; 2) engage the stakeholders using a survey to identify breeding priorities (i.e. breeding traits, breeding practices); 3) outline objectives of a full SCRI grant proposal that will enlarge the genetic, genomic and phenotypic resources of blueberry and cranberry, and develop tools to accelerate the selection of improved cultivars. The project involved 25 collaborators from 14 institutions including blueberry and cranberry breeders and allied scientists who are experts in plant pathology, entomology, food science, post-harvest physiology, genetics and genomics, economy and extension and crop production.

Overall, industry responses signaled that the most important trait clusters were fruit quality, particularly firmness, flavor, and shelf life. These traits affect price premiums received by producers, influence consumer preference and demand, and can increase mechanical harvest and packing operation efficiency by reducing physical damage of the fruits, all of which are critical to the economic viability of the industry. There were differences across regions and states in the relative importance assigned to traits for disease resistance, insect resistance, and tolerance to abiotic stresses. These findings will be useful to breeders and allied scientists seeking to develop accelerated DNA based selection strategies to develop cultivars with improved traits for the North American blueberry industry.

Introduction

North America is the largest worldwide producer of cranberries and blueberries, and the U.S. leads production of both crops. These crops are amongst the very few native North American crops and are closely related members of the Vaccinium genus. Recognition of the health benefits of cranberry and blueberry consumption have contributed to a rapid increase in production over the last few decades. However, both industries are facing new challenges including management restrictions involving labor, emerging disease and insect pressures with concurrent restriction of pest control measures, changing fruit quality standards and new product needs criteria, as well as a changing climate. Consequently, the production and processing industries face a need for new cultivars with improved or tailored characteristics to meet dynamic industry and market challenges. To satisfy these needs, U.S. Vaccinium stakeholders consider breeding improved cultivars a high priority. Indeed, grower associations representing the blueberry and cranberry industries at the state or regional levels routinely provide financial and strategic support to public institutions to sustain existing breeding programs. However, resources are lacking to take these efforts to the next level and develop the necessary genomic and genetic resources and tools to integrate genomic information with high-throughput phenotyping to accelerate the development of new cultivars with improved attributes. Such a coordinated genomics-based approach has been highly successful in other fruit crop groups such as the Rosaceae, but is currently lacking in Vaccinium. This lack of a formal coordinated multi-state research program limits the efficient development of interdisciplinary and transformational research programs with long-term goals for effective integration of research and extension activities with stakeholder needs. In addition, since the application of this technology requires extensive training, knowledge, and significant investments it is critical to focus on the genetic traits of maximum value. Hence, the overall goal of this study was to identify and coordinate research priorities and breeding trait targets based on the various industry sectors and plan to further integrate genomic/phenotypic data to develop a sustainable technical platform to accelerate and increase the efficiency of cultivar development and adoption. The potential of genomic approaches to enhance crop improvement, particularly through genomic selection, is enormous. Genomics research has not yet been translated into routine practical breeding application in cranberry or blueberry breeding.

Methods

Research priorities from 6 state and provincial blueberry commodity groups (Michigan, Washington, North Carolina, Georgia, California, and British Columbia-Canada) and two national or regional research organizations (Small Fruit Crop Germplasm Committee and Northwest Center for Small Fruits Research) were extracted from recent research grant proposal requests and research priority recommendations to create an initial list of production-related needs and to identify clusters of fruit and plant traits that could directly or indirectly provide benefits to the blueberry industry. The blueberry industry refers to nurseries, producers, packers, processors, breeders, and non-breeder researchers. Six trait clusters were identified heuristically from this list including: (1) fruit quality, (2) disease resistance, (3)

insect pest resistance, (4) plant stress tolerance, (5) other plant traits, and (6) machine harvestability. The survey was designed around these 6 trait clusters and 62 specific fruit and plant traits. The fruit quality cluster included 10 traits, the disease resistance cluster included 18 traits, the insect pest resistance cluster included 16 traits, the plant stress tolerance cluster included 5 traits, the other plant traits cluster included 4 traits, and the machine harvestability cluster included 8 traits.

The survey asked participants to rank the importance of traits to their farming operation in the 6 trait clusters (question 1-6) and overall (question 7). Within each cluster, we asked the respondent to rank the 1st, 2nd, 3rd, etc. most important and the 1st, 2nd, 3rd, etc. least important trait for a successful cultivar. Note that each cluster of traits included an “other trait” option, in case we missed an important trait in the selected list of traits presented to the respondents.

Other questions in the survey included categorical questions to define the respondent’s role in the supply chain (e.g., grower, nursery operator, packer, processor, breeder, and non-breeder scientist); the size of the blueberry operation expressed in cultivated area; the number of years involved in the decision-making process of the blueberry operation; the list of blueberry cultivars with the largest cultivated area in the blueberry operation; whether a new cultivar was planted during the last 5 years; and the name of the state where the largest cultivated area of the blueberry operation was located.

The blueberry industry survey was conducted at grower meetings across nine U.S. states and British Columbia (Canada) between November 2016 and March 2017. The names of the meetings were: (1) Massachusetts Cultivated Blueberry Growers Association in Massachusetts in November 2016; (2) Lynden Small Fruit Conference in Washington in December 2016; (3) Alma Blueberry Update in Georgia in January 2017; (4) Florida Blueberry Growers Association in January 2017; (5) Oregon Blueberry Conference in January 2017; (6) Lower Mainland Horticulture Improvement Association in British Columbia (Canada) in January 2017; (7) Great Lakes Expo in Michigan in January 2017; (8) N.C. Blueberry Open House and Trade Show in January 2017; (9) Gulf South Blueberry Growers Association in Mississippi in January 2017 and (10) Blueberry Open House in New Jersey in March 2017.

At each meeting, a scientist and/or extension educator associated with this study was given a time slot for a presentation, and during or before the presentation a paper-based survey was distributed to the audience. The collaborator presented the content and the objective of the survey while the audience responded to the survey.

The survey form, which was approved by the Institutional Review Board, Washington State University IRB #15708, is available at the Vaccinium Planning Project webpage https://pgnglab.plantsforhumanhealth.ncsu.edu/vaccinium-project/survey/

Results

We obtained 375 responses from 12 U.S. states and one Canadian province (**Table 1**). The 12 U.S. states and one Canadian province included in the survey responses account for over 99% of the U.S. production, 98.6% of U.S. and Canada blueberry production and 93.7% of the North American production. On average across regions, 84% of respondents were producers, 9% were associated with packing houses, 6% with blueberry processing companies, 5% had other roles in the industry, 3% were associated with nurseries, 3% were non-breeder researchers, and 1% were breeders (**Table 2**). Note that these numbers do not add to 100% as some respondents marked more than one category. Across regions, the Northwest, including the states of WA, OR, and the Canadian province BC, represented the most diversified industry respondents (**Table 2-3**).

The average size of the blueberry operations was 49.8 ha (**Table 4**). This size varied across regions, with the largest size in acres in the Midwest (78.1 ha), followed by the Northeast (68.8 ha), West (54.2 ha), and Southeast (35.6 ha). Michigan and New Jersey included the highest percent respondents managing operations (24% and 26.5%, respectively) >500 ha (**Table 4-5**).

Average number of years involved in the decision-making process of blueberry operations was 10.3 years (**Table 6**). The years of experience varied across regions with the Northeast averaging 15 years, Midwest 12 years, West 10 years, and Southeast 9 years. Survey responses from CA, WA and OR and FL included the highest percent of respondents with 1-5 years of experience while responses from MA, NJ and TN included the highest percent of respondents with >20 years of experience (**Table 7**).

On average across all regions and states surveyed, 51% of respondents felt that fruit quality was most important, 18.9% indicated disease resistance, and 16.5% indicated machine harvestability (**Table 8-9**). Although, machine harvestability ranked 3rd in importance overall, it is the second most important trait cluster in the West, Midwest and Northeast and ranked 3rd after disease resistance in Southeast states with the exception of NC (**Table 9**). Thirty-four percent of respondents indicated that firmness was the most important fruit quality attribute, 24% indicated it was flavor and 15% shelf life (**Table 10**). Ranking of these 3 traits were very consistent across regions and states with the exception of respondents from BC who indicated that shelf life followed by flavor and fruit size were the most important traits (**Table 11**).

Sixteen percent of respondents indicated that the most important disease resistance trait was resistance to fruit rot and 14% indicated resistance for mummy berry was the most important (**Table 12-13**). Although resistance to fruit rot ranked the most important trait overall, mummy berry ranked the most important traits across seven states, while resistance to fruit rot was ranked the most important trait in four states particularly in MI and NJ (**Table 13**). One notable difference across states was ranking of the disease resistance trait for blueberry scorch virus, which was ranked the most or second most important disease resistance trait in BC, CA, WA and NJ.

Fifty-nine percent of respondents indicated that resistance to SWD was the most important insect pest resistance trait (**Table 14-15**). These results were highly consistent across all

regions and state. Ranking differences for the other insect resistance traits were observed across the states. For example, resistance to flower thrips was the second most important trait in FL, resistance to blueberry maggot was the second most important trait in NC, GA, OR and MI, and resistance to aphids was the second most important trait in MA, WA, BC and NJ (**Table 15**).

Thirty-three percent of respondents indicated frost tolerance as the most important abiotic stress tolerance trait (**Table 16**). Differences across regions and state were very evident (**Table 16-17**). Tolerance to heat/UV damage ranked as the most important trait in the West particularly in WA and BC. Winter hardiness ranked as the most important trait in the Midwest and frost tolerance ranked the most important trait in the Northeast and Southeast. Ranking differences for the other abiotic stress tolerance traits were observed across the states (**Table 17**). For example, drought tolerance ranked as the most or second most important trait in NC, MA, MS, FL, and AL. Soil type adaption, ranked as the most or second most important trait in FL, GA, OR and BC.

Forty-one percent of respondents indicated that yield was the most important other plant trait, and 32% indicated that it was ripening time (**Table 18**). These results were consistent across all regions and states (**Table 18-19**) with few exceptions. For example, ripening time ranked the most important trait in FL and MS, self-pollination ranked the second most important trait in NC, MA, and CA, flowering time ranked the second most important trait in NJ (**Table 19**).

Fifty-five percent of respondents indicated that fruit firmness was the most important trait for machine harvestability and 17% of respondents indicated that it was uniform ripening (**Table 20**). These results were consistent across all regions and states (**Table 20-21**) with very few exceptions. For example, loose clusters ranked as the second most important trait in NC.

Dominant blueberry cultivars. Respondents were asked to list the four most predominant cultivars currently growing in their fields. A total of 27 northern highbush (NHB), 8 rabbiteye, and 25 southern highbush (SHB) cultivars were reported in the survey. Overall, ‘Duke’ was the most predominant cultivar in production followed by ‘Bluecrop’ and ‘Emerald’ (**Table 22**). As expected, however, there was a wide diversity of cultivars depending on geographic location. The more cold-hardy NHB cultivars like Duke, Jersey, Aurora, Draper and Liberty predominate in the northern U.S. and Canada, whereas rabbiteye ‘Brightwell’ and the SHB cultivars Emerald, Star, Farthing, and Jewel are predominant in the Southern states (**Table 22**).

To evaluate promising cultivars and the percentage of producers replanting the same cultivars, respondents were asked if they had replanted a blueberry field in the last 5 years and to list the most predominant cultivar planted. Farthing (22 producers) followed by Draper (21) and Duke (20), were the most predominant cultivars used in replanted fields (**Table 22**). Considering the seven most predominant replanted cultivars, on average, 31% of the respondents re-adopted the same cultivar (**Table 23**). Finally, the percentage of blueberry operations that replanted the same cultivars was low (avg. 31%), suggesting that respondents are willing to take risks to increase investment returns by adopting different cultivars with improved characteristics.

Table 1. Summary statistics of blueberry industry survey responses by region and states/provinces.

Regions	States/Province	N=375
Southeast, N= 155	Georgia	69
	Florida	52
	North Carolina	19
	Mississippi	13
	Tennessee	2
	Alabama	1
West, N= 149	Oregon	84
	British Columbia,	44
	Washington	17
	California	4
Northeast, N= 41	New Jersey	33
	Massachusetts	8
Midwest, N=29	Michigan	29

Table 2. Respondents' occupations by regions (survey Q8)

Occupation	Percentage of respondents				
	West	Midwest	NorthEast	SouthEast	Avg.
Grower	69.1	90.0	95.2	97.7	83.8
Nursery	4.8	3.3	2.4	2.6	3.5
Processer	10.9	0.0	0.0	3.3	5.6
Packing house	10.9	0.0	0.0	11.3	9.3
Breeder	2.7	0.0	0.0	0.0	1.1
Non-breeding researcher	4.8	3.3	0.0	2.0	2.9
Other	10.2	3.3	2.4	2.0	5.3

Table 3. Respondents' occupations by States (survey Q8)

Occupation	Percentage of respondents													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Grower	100.0	89.9	87.5	67.1	83.3	53.3	77.3	96.2	90.0	97.1	50.0	100.0	100.0	83.8
Nursery	0.0	4.3	0.0	3.5	0.0	5.9	4.6	0.0	3.3	2.9	50.0	50.0	0.0	3.5
Processer	0.0	4.3	0.0	12.9	7.7	17.7	4.6	0.0	0.0	0.0	0.0	50.0	0.0	5.6
Packing house	28.6	14.3	0.0	14.1	15.4	11.8	4.6	1.9	0.0	0.0	0.0	50.0	0.0	9.3
Breeder	0.0	0.0	0.0	2.4	0.0	0.0	2.3	0.0	0.0	0.0	50.0	0.0	0.0	1.1
Non-breeding researcher	0.0	0.0	0.0	3.5	15.4	11.8	4.6	1.9	3.3	0.0	0.0	0.0	0.0	2.9
Other	0.0	4.3	12.5	11.8	0.0	17.7	9.1	0.0	3.3	0.0	0.0	0.0	0.0	5.3

Table 4: Size of operation summarized by regions (survey Q9)

State	Percentage of respondents who expressed their blueberry operation fall into the corresponding size category (size in acres)								Avg. size in acres (St. Dev.)
	<5	5-14	15-24	25-49	50-99	100-249	250-499	>500	
West	21.1	7.0	7.8	12.5	14.8	18.0	7.8	10.9	134.1 (164.3)
Midwest	20.0	8.0	8.0	12.0	8.0	8.0	12	24.0	192.5 (211.2)
NorthEast	28.6	7.1	2.38	9.5.0	7.1	19.1	4.8	21.4	169.6 (196.8)
SouthEast	10.0	17.9	12.1	23.6	15.7	10.0	6.4	4.3	87.9 (128.1)

Table 5: Size of operation summarized by States (survey Q9)

State	Percentage of respondents who expressed their blueberry operation fall into the corresponding size category (size in acres)								Avg. size in acres (St. Dev.)
	<5	5-14	15-24	25-49	50-99	100-249	250-499	>500	
North Carolina	21.4	7.1	0.0	0.0	7.1	35.7	21.4	7.1	185.4 (163.6)
Georgia	4.6	20.0	9.2	26.2	20.0	10.8	6.2	3.1	85.7 (118.3)
Massachusetts	87.5	12.5	0.0	0.0	0.0	0.0	0.0	0.0	5.6 (1.6)
Oregon	24.3	2.7	5.4	9.5	18.9	21.6	5.4	12.2	138.9 (163.9)
Mississippi	25.0	8.3	25	33.3	0.0	8.3	0.0	0.0	33.8 (46.3)
Washington	16.7	16.7	8.3	0.0	0.0	25	25	8.3	183.0 (181.2)
British Columbia	10.5	10.5	13.2	23.7	13.2	13.2	7.9	7.9	114.4 (152.7)
Florida	8.7	19.6	17.4	26.1	17.4	2.2	4.4	4.4	70.0 (120.0)
Michigan	20.0	8.0	8	12.0	8.0	8.0	12	24.0	192.5 (211.2)
New Jersey	14.7	5.9	2.9	11.8	8.8	23.5	5.9	26.5	208.2 (200.2)
California	75.0	50	0.0	0.0	0.0	0.0	0.0	0.0	6.1 (2.3)
Tennessee	50.0	0.0	0.0	0.0	0.0	0.0	0.0	50	252.5 (350.0)
Alabama	0.0	100	0.0	0.0	0.0	0.0	0.0	0.0	9.5 (0.0)

Table 6. Number of years involved in the decision-making process summarized by regions (survey Q10)

State	Percentage of respondents who expressed their number of years involved in the decision-making process fall into the corresponding year category					Avg. years (St. dev.)
	1-5	6-10	11-15	16-20	>20	
West	37.4	22.9	15.3	9.2	15.3	9.64 (6.48)
Midwest	22.2	25.9	18.5	0.0	33.3	11.81 (6.73)
NorthEast	14.6	17.1	9.8	4.9	53.7	14.68 (6.68)
SouthEast	32.9	30.1	18.9	4.9	13.3	9.38 (5.94)

Table 7. Number of years involved in the decision-making process summarized by States (survey Q10)

State	Percentage of respondents who expressed their number of years involved in the decision-making process fall into the corresponding year category					Avg. years (St. dev.)
	1-5	6-10	11-15	16-20	>20	
North Carolina	28.6	7.1	21.4	7.1	35.7	12.6 (7.30)
Georgia	35.3	29.4	16.2	4.4	14.7	9.2 (6.12)
Massachusetts	0.0	0.0	14.3	0.0	85.7	19.0 (2.65)
Oregon	42.3	19.2	12.8	7.7	18.0	9.4 (6.77)
Mississippi	25.0	25.0	41.7	0.0	8.3	9.8 (5.25)
Washington	40.0	26.7	20.0	13.3	0.0	8.3 (5.50)
British Columbia	22.9	28.6	20.0	11.4	17.1	11.1 (6.21)
Florida	34.8	39.1	17.4	6.5	2.2	8.0 (4.82)
Michigan	22.2	25.9	18.5	0.0	33.3	11.1 (6.73)
New Jersey	17.7	20.6	8.8	5.9	47.1	13.8 (6.94)
California	75.0	25.0	0.0	0.0	0.0	4.3 (2.50)
Tennessee	0.0	50.0	0.0	0.0	50.0	14.0 (8.49)
Alabama	0.0	0.0	0.0	0.0	100.0	20.0 (0.00)

Table 8. The MOST important group of characteristics for a new cultivar by regions (survey Q7)

Group of characteristics	Percentage of respondents who marked each category as the MOST important group of characteristics for a new cultivar				
	West	Midwest	NorthEast	SouthEast	Avg.
Fruit quality traits	57.8	51.6	47.6	47.1	51.7
Disease resistance	12.9	9.7	19.1	26.1	18.9
Insect pest resistance	4.1	0.0	4.8	0.7	2.4
Plant stress tolerance	2.7	3.2	4.8	7.2	4.8
Other plant characteristics	2.7	3.2	4.8	1.3	2.4
Machine harvestability	15.0	19.4	19.1	17.0	16.5

Table 9. The MOST important group of characteristics for a new cultivar by States (survey Q7)

Group of characteristics	Percentage of respondents who marked each category as the MOST important group of characteristics for a new cultivar													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Fruit quality traits	42.9	42.9	37.5	68.2	53.9	58.8	38.6	50.9	51.6	50.0	50.0	50.0	100.0	51.7
Disease resistance	7.1	25.7	37.5	7.1	23.1	5.9	22.7	34.0	9.7	14.7	50.0	0.0	0.0	18.9
Insect pest resistance	0.0	0.0	12.5	5.9	7.7	0.0	2.3	0.0	0.0	2.9	0.0	0.0	0.0	2.4
Plant stress tolerance	7.1	11.4	0.0	1.2	0.0	0.0	6.8	3.8	3.2	5.9	0.0	0.0	0.0	4.8
Other plant characteristics	0.0	0.0	12.5	1.2	0.0	11.8	2.3	1.9	3.2	2.9	0.0	50.0	0.0	2.4
Machine harvestability	42.9	21.4	0.0	14.1	15.4	23.5	15.9	5.7	19.4	23.5	0.0	0.0	0.0	16.5

Table 10. The MOST important fruit quality trait summarized by regions (survey Q1)

Fruit quality trait	Percentage of respondents who marked each category as the MOST important fruit quality trait				
	West	Midwest	North East	South East	Avg.
Firmness	36.7	20.0	30.1	33.9	33.9
Flavor	24.5	40.0	30.9	18.9	24.0
Shelf life	15.7	20.0	9.5	13.7	14.4
Shape/appearance	5.4	3.3	4.8	11.1	7.7
Color	4.8	3.3	7.1	4.6	4.8
Size	2.7	10.0	9.5	4.6	4.8
Sweetness	2.7	0.0	0.0	3.9	2.6
Other fruit quality traits	1.4	3.3	4.8	3.3	2.7
Crispness	2.0	0.0	0.0	2.6	1.9
Nutritional benefit	2.0	0.0	0.0	2.6	1.9
Small dry stem scar	2.0	0.0	0.0	0.7	1.1

Table 11. The MOST important fruit quality trait summarized by States (survey Q1)

Fruit quality trait	Percentage of respondents who marked each category as the MOST important fruit quality trait													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Firmness	35.7	34.3	12.5	31.8	38.5	41.2	0.0	34.0	20.0	35.3	0.0	0.0	0.0	33.9
Flavor	35.7	17.1	62.5	28.2	30.8	23.5	13.6	11.3	40.0	23.5	50.0	100.0	0.0	24.0
Shelf life	21.4	15.7	0.0	20.0	15.4	5.9	15.9	9.4	20.0	11.8	25.0	0.0	0.0	14.4
Shape/appearance	0.0	7.1	0.0	7.1	15.4	5.9	2.3	18.9	3.3	5.9	0.0	0.0	0.0	7.7
Color	0.0	7.1	12.5	4.7	0.0	5.9	4.6	3.8	3.3	5.9	0.0	0.0	0.0	4.8
Size	0.0	5.7	0.0	0.0	0.0	0.0	9.1	3.8	10.0	11.8	0.0	0.0	100.0	4.8
Sweetness	7.1	1.4	0.0	2.3	0.0	0.0	2.3	7.6	0.0	0.0	25.0	0.0	0.0	2.7
Other fruit quality traits	0.0	1.4	0.0	0.0	0.0	11.8	0.0	7.6	3.3	5.9	0.0	0.0	0.0	2.7
Crispness	0.0	2.9	0.0	3.5	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	1.9
Nutritional benefit	0.0	5.7	0.0	2.3	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Small dry stem scar	0.0	1.4	0.0	2.3	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1

Table 12: The MOST important disease resistance trait summarized by regions (survey Q2)

Disease resistance trait	Percentage of respondents who marked each category as the MOST important disease resistance trait				
	West	Midwest	North East	South East	Avg.
Anthracnose fruit rot	6.8	35.5	42.9	14.4	16.3
Mummy berry	19.7	3.2	4.8	13.7	14.1
Bacterial leaf scorch	1.4	0.0	0.0	9.8	9.5
Phytophthora root rot	11.6	3.2	7.1	8.5	9.1
Botrytis flower blight and fruit rot	10.2	0.0	4.8	9.2	8.5
Blueberry scorch virus	12.9	9.7	9.1	2.6	8.0
Shock virus	11.6	0.0	4.8	0.7	5.3
Stem blight	1.4	3.2	2.4	10.5	5.3
fungal leaf spots, rust disease	2.7	3.2	2.4	7.2	4.5
Alternaria fruit rot	4.8	12.9	0.0	32.0	4.3
Exobasidium leaf and fruit spot	0.7	0.0	0.0	5.9	2.7
Algal stem blotch	1.4	0.0	0.0	3.9	2.1
Phomopsis twig blight	0.7	9.7	9.5	0.0	2.1
Bacterial blight/canker	2.0	3.2	0.0	1.3	1.6
Other disease	0.0	3.2	4.8	2.0	1.6
Blueberry Stunt	0.7	0.0	4.8	1.3	1.3
Nematodes	1.4	0.0	2.4	1.3	1.3
Stem canker	0.0	3.2	0.0	1.3	0.8
Necrotic ring blotch virus	0.0	0.0	0.0	0.7	0.3

Table 13. The MOST important disease resistance trait summarized by States (survey Q2)

Disease resistance trait	Percentage of respondents who marked each category as the MOST important disease resistance trait													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Anthracnose fruit rot	14.3	15.7	12.5	5.9	0.0	0.0	11.4	17.0	35.5	50.0	0.0	0.0	0.0	16.3
Mummy berry	28.6	14.3	25.0	23.5	23.1	23.5	11.4	3.8	3.2	0.0	0.0	50.0	100.0	14.1
Bacterial leaf scorch	7.1	11.4	0.0	0.0	0.0	0.0	4.6	11.3	0.00	0.0	0.0	0.0	0.0	9.5
Phytophthora root rot	0.0	8.6	12.5	12.9	7.7	11.8	6.8	11.3	3.2	5.9	25.0	0.0	0.0	9.1
Botrytis flower blight and fruit rot	0.0	12.9	0.0	12.9	7.7	5.9	13.6	7.6	0.00	5.9	0.0	0.0	0.0	8.5
Blueberry scorch virus	0.0	2.9	0.0	5.9	7.7	17.7	22.7	1.9	9.7	8.8	25.0	0.0	0.0	8.0
Shock virus	0.0	0.0	0.0	12.9	0.0	17.7	6.8	1.9	0.00	5.9	0.0	0.0	0.0	5.3
Stem blight	7.1	8.6	0.0	2.4	7.7	0.0	0.0	13.2	3.2	2.9	0.0	50.0	0.0	5.3
fungal leaf spots, rust disease	7.1	2.9	12.5	2.4	0.0	5.9	0.0	15.1	3.2	0.0	25.0	0.0	0.0	4.5
Alternaria fruit rot	7.1	5.7	0.0	4.7	0.0	5.9	4.6	0.0	12.9	0.0	0.0	0.0	0.0	4.3
Exobasidium leaf and fruit spot	7.1	8.6	0.0	1.2	15.4	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	2.7
Algal stem blotch	7.1	1.4	0.0	1.2	7.7	0.0	2.3	5.7	0.0	0.0	0.0	0.0	0.0	2.1
Phomopsis twig blight	0.0	0.0	25.0	1.2	0.0	0.0	0.0	0.0	9.7	5.9	0.0	0.0	0.0	2.1
Bacterial blight/canker	0.0	1.4	0.0	0.0	0.0	11.8	2.3	1.9	3.2	0.0	0.0	0.0	0.0	1.6
Other disease	0.0	0.0	12.5	0.0	0.0	0.0	0.0	5.7	3.2	2.9	0.0	0.0	0.0	1.6
Blueberry Stunt	7.1	1.4	0.0	0.0	0.0	0.0	2.3	0.0	0.0	5.9	0.0	0.0	0.0	1.3
Nematodes	7.1	1.4	0.0	1.2	0.0	0.0	2.3	0.0	0.0	2.9	0.0	0.0	0.0	1.3
Stem canker	0.0	0.0	0.0	0.0	7.7	0.0	0.0	1.9	3.2	0.0	0.0	0.0	0.0	0.8
Necrotic ring blotch virus	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3

Table 14. The MOST important insect pest resistance trait summarized by regions (survey Q3)

Insect pest resistance trait	Percentage of respondents who marked each category as the MOST important insect pest resistance trait				
	West	Midwest	North East	South East	Avg.
Aphids	6.8	3.2	14.3	1.3	5.1
Blueberry maggot	3.4	12.9	4.8	11.8	7.7
Brown marmorated stink	4.8	0.0	2.4	1.3	2.7
Bud mite	0.7	0.0	0.0	3.9	1.9
Cherry fruitworm	2.0	3.2	0.0	1.3	1.6
Cranberry fruitworm	0.0	0.0	0.0	0.0	0.0
Flower thrips	1.4	0.0	0.0	15.0	6.7
Gall midge	0.0	3.2	0.0	6.5	2.9
Plum curculio	0.7	0.0	4.8	0.0	0.8
Scale insects	1.4	3.2	0.0	0.7	1.1
Sharp nosed leafhopper	0.0	0.0	2.4	2.0	1.1
Spotted wing drosophila	70.8	54.8	54.8	50.3	59.5
Stem borers	0.0	0.0	0.0	1.3	0.5
Stem gall wasp	0.0	12.9	2.4	0.0	1.3
White grubs (roots)	0.7	0.0	4.8	0.0	0.8
Winter moth	0.0	0.0	9.5	0.7	1.3
Other insects	0.0	0.0	0.0	2.0	0.8

Table 15. The MOST important insect pest resistance trait summarized by States (survey Q3)

Insect pest resistance trait	Percentage of respondents who marked each category as the MOST important insect pest resistance trait													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Aphids	7.1	1.4	12.5	3.5	0.0	11.8	11.4	0.0	3.2	14.7	0.0	0.0	0.0	5.1
Blueberry maggot	14.3	15.7	0.0	4.7	0.0	0.0	2.3	9.4	12.9	5.9	0.0	0.0	0.0	7.7
Brown marmorated stink	7.1	0.0	0.0	3.5	0.0	0.0	6.8	1.9	0.0	2.9	25.0	0.0	0.0	2.7
Bud mite	0.0	4.3	0.0	0.0	0.0	5.9	0.0	5.7	0.0	0.0	0.0	0.0	0.0	1.9
Cherry fruitworm	7.1	0.0	0.0	3.5	0.0	0.0	0.0	1.9	3.2	0.0	0.0	0.0	0.0	1.6
Cranberry fruitworm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flower thrips	0.0	15.7	0.0	2.4	0.0	0.0	0.0	22.6	0.0	0.0	0.0	0.0	0.0	6.7
Gall midge	0.0	2.9	0.0	0.0	7.7	0.0	0.0	13.2	3.2	0.0	0.0	0.0	0.0	2.9
Plum curculio	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.8
Scale insects	0.0	1.4	0.0	1.2	0.0	0.0	0.0	0.0	3.2	0.0	25.0	0.0	0.0	1.1
Sharp nosed leafhopper	0.0	1.4	0.0	0.0	0.0	0.0	0.0	3.8	0.0	2.9	0.0	0.0	0.0	1.1
Spotted wing drosophila	64.3	52.9	37.5	72.9	84.6	82.3	68.2	32.1	54.8	58.8	0.0	100.0	100.0	59.5
Stem borers	0.0	1.4	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	25.0	0.0	0.0	0.5
Stem gall wasp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	2.9	0.0	0.0	0.0	1.3
White grubs (roots)	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.8
Winter moth	0.0	0.0	50.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.3
Other insects	0.0	1.4	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.8

Table 16. The MOST important stress factor summarized by regions (survey Q4)

Stress factor	Percentage of respondents who marked each category as the MOST important stress factor				
	West	Midwest	NorthEast	SouthEast	Avg.
Frost tolerance	23.1	16.1	35.7	45.8	33.3
Heat tolerance/UV damage	33.3	6.5	4.8	7.2	17.1
Drought resistance	12.9	6.5	14.3	17.7	0.3
Winter hardiness	7.5	54.8	31.0	8.5	14.4
Soil type adaptation	17.7	6.5	9.5	17.7	16.0
Other stress	0.7	3.2	2.4	1.3	1.3

Table 17. The MOST important stress factor summarized by States (survey Q4)

Stress factor	Percentage of respondents who marked each category as the MOST important stress factor													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Frost tolerance	21.4	65.7	25.0	14.1	53.9	29.4	40.9	24.5	16.1	38.2	25.0	50.0	0.0	33.3
Heat tolerance/UV damage	7.1	8.6	0.0	50.6	7.7	17.7	6.8	5.7	6.5	5.9	0.0	0.0	0.0	17.1
Drought resistance	35.7	5.7	25.0	11.8	15.4	11.8	13.6	28.3	6.5	11.8	25.0	0.0	100.0	0.3
Winter hardiness	21.4	8.6	12.5	5.9	0.0	17.7	6.8	5.7	54.8	35.3	0.0	50.0	0.0	14.4
Soil type adaptation	14.3	10.0	12.5	16.5	15.4	17.7	20.5	30.2	6.5	8.8	25.0	0.0	0.0	16.0
Other stress	0.0	0.0	12.5	0.0	0.0	5.9	0.0	3.8	3.2	0.0	0.0	0.0	0.0	1.3

Table 18. The MOST important other plant trait summarized by regions (survey Q5)

Other plant trait	Percentage of respondents who marked each category as the MOST important other plant trait				
	West	Midwest	NorthEast	SouthEast	Avg.
Flowering time	8.2	16.1	23.8	20.9	15.7
Ripening time	32.7	25.8	19.1	36.6	32.3
Self-pollination	6.8	6.5	16.7	8.5	8.8
Yield	46.9	45.2	38.1	34.6	40.5
Other plant traits	1.4	0.0	2.4	0.7	1.1

Table 19. The MOST important other plant trait summarized by States (survey Q5)

Other plant trait	Percentage of respondents who marked each category as the MOST important other plant trait													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Flowering time	21.4	24.3	0.0	4.7	23.1	11.8	13.6	15.1	16.1	29.4	0.0	0.0	100.0	15.7
Ripening time	14.3	32.9	25.0	40.0	38.5	17.7	27.3	49.1	25.8	17.7	0.0	0.0	0.0	32.3
Self-pollination	28.6	11.4	37.5	3.5	7.7	11.8	9.1	0.0	6.5	11.8	25.0	0.0	0.0	8.8
Yield	42.9	32.9	37.5	51.8	30.8	58.8	34.1	34.0	45.2	38.2	50.0	100.0	0.0	40.5
Other plant traits	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.9	0.0	2.9	25.0	0.0	0.0	1.1

Table 20. The MOST important machine harvestability factor for a successful cultivar summarized by regions (survey Q6).

Machine harvestability factor	Percentage of respondents who marked each category as the MOST important machine harvestability factor				
	West	Midwest	NorthEast	SouthEast	Avg.
Fruit firmness	58.5	61.3	47.6	53.6	55.7
Loose clusters	4.1	3.2	0.0	10.5	6.1
Monopodial stem	1.4	0.0	2.4	2.6	1.9
Small dry stem scar	0.0	3.2	4.8	0.0	0.8
Uniform ripening	19.7	9.7	16.7	15.7	16.8
Upright growth	4.1	3.2	4.8	7.2	5.3
Narrow habit	1.4	0.0	0.0	1.3	1.1
Flexible canes	0.7	0.0	2.4	3.3	1.9
Other traits related to machine harvestability	0.7	0.0	0.0	0.0	0.3

Table 21. The MOST important machine harvestability factor for a successful cultivar summarized by States (survey Q6).

Machine harvestability factor	Percentage of respondents who marked each category as the MOST important machine harvestability factor													
	NC	GA	MA	OR	MS	WA	BC	FL	MI	NJ	CA	TN	AL	Avg.
Fruit firmness	71.4	54.3	0.0	57.7	53.9	82.4	52.3	49.1	61.3	58.8	50.0	0.0	100.0	55.7
Loose clusters	21.4	10.0	0.0	3.5	7.7	0.0	6.8	9.4	3.2	0.0	0.0	0.0	0.0	6.1
Monopodial stem	0.0	5.7	0.0	2.4	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	1.9
Small dry stem scar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	5.9	0.0	0.0	0.0	0.8
Uniform ripening	7.1	17.1	12.5	22.4	15.4	11.8	20.5	17.0	9.7	17.7	0.0	0.0	0.0	16.8
Upright growth	0.0	5.7	0.0	4.7	0.0	0.0	4.6	9.4	3.2	5.9	0.0	100.0	0.0	5.3
Narrow habit	0.0	2.9	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Flexible canes	0.0	1.4	12.5	0.0	7.7	0.0	2.3	5.7	0.0	0.0	0.0	0.0	0.0	1.9
Other traits related to machine harvestability	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3

Table 22. Number of respondents indicating which varieties represented the largest acreage in their operation, and which varieties were planted in the last 5 years with the largest acreage (survey Q11-12).

	Current varieties being planted with the largest acreage, number of responses														
	Duke	Bluecrop	Farthing	Legacy	Draper	Liberty	Rebel	Emerald	Star	Brightwell	Jersey	Premier	Aurora	Jewel	Elliott
West	62	12	0	10	7	7	0	0	0	0	0	1	8	0	1
Midwest	0	9	0	0	1	1	1	0	0	0	10	0	0	0	4
Northeast	13	12	0	0	0	0	0	0	0	0	7	0	0	0	2
Southeast	0	1	15	4	0	0	3	28	22	20	0	9	0	8	0
Total	75	34	15	14	8	8	4	28	22	20	17	10	8	8	7

	Newly planted varieties with the largest acreage, number of responses						
	Duke	Bluecrop	Farthing	Legacy	Draper	Liberty	Rebel
West	14	1	0	7	11	10	0
Midwest	1	2	0	0	0	1	0
Northeast	5	3	0	0	8	1	1
Southeast	0	0	22	6	2	0	6
Total	20	6	22	13	21	12	7

Table 23. Replanting distribution of current blueberry cultivars with new blueberry cultivars based on an industry survey conducted in 2016/17.

Current variety	Newly planted variety						
	Duke	**Bluecrop**	**Farthing**	**Legacy**	**Draper**	**Liberty**	**Rebel**
	Percentage of respondents						
Duke (N=75)	17%	0%	0%	0%	17%	7%	0%
Bluecrop (N=34)	6%	15%	0%	3%	9%	6%	0%
Farthing (N=15)	0%	0%	53%	0%	0%	0%	7%
Legacy (N=14)	21%	0%	0%	50%	0%	0%	0%
Draper (N=8)	25%	0%	0%	0%	38%	0%	0%
Liberty (N=8)	0%	0%	0%	0%	13%	25%	0%
Rebel (N=4)	0%	0%	0%	0%	0%	0%	0%