



Annual Report 2011: Hard Cider
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TITLE : Evaluation of Apple Varieties for Hard Cider Production

PERSONNEL:

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OBJECTIVES:

1. To evaluate certain hard cider apple varieties and determine bloom dates, fruit set, and juice characteristics (brix, pH, percent acid, percent tannin) in northwest Washington.
2. To test mechanical harvest of cider apples with a berry harvester and evaluate impact on fruit yield and quality.

SUMMARY: Bottling of 2 cider apples harvested in 2010 was done in January 2011, and 9 cider apple varieties were harvested and pressed for cider making in 2011; they will be bottled Spring 2012. Observations of bloom time and bloom density of 62 cultivars were recorded in April-May 2011. At harvest, juice samples were collected from 59 cider apple varieties grown at WSU Mount Vernon NWREC, and analyzed for percent tannin, brix, pH and titratable acid. A replicated trial comparing machine harvest of cider apples with hand harvest was conducted on October 25, 2011. Cider School courses were conducted at WSU Mount Vernon NWREC by the Northwest Agriculture Business Center; introductory courses were held June 27-July 1 and December 12-16, 2011.

METHODS:

Our field planting currently includes a total of 60 cider apple varieties in 3 field blocks:

Block 1: 31 cider apple varieties of 3 - 5 trees each, includes: 6 varieties established in 1994; from 1999 to 2005, 3 varieties were removed and 14 were added; in 2005, 7 new varieties were added; in 2006 an additional 7 varieties were added;

Block 2: A trellis planting of 5 cider apple varieties selected from the original varieties in Block 1, in 4 rows closely spaced (3x12, 4x12, 5x12 and 6x12) on strongly dwarfing rootstocks (M27 and M9) with 40-60 trees per row, established to investigate mechanical harvest;

Block 3: 29 cider apple varieties, single trees planted in 2004 and 2006; includes classic American cider varieties and other varieties from the European cider making centers of England and France.

Observations for varieties not previously evaluated included recording of bloom date and density once a week, beginning in early May to mid-June 2011. Fruit maturity was evaluated weekly during the harvest season using the starch conversion iodine test as a ripeness indicator for picking. Juice of 61 varieties (2 from cooperator's orchard) was analyzed for brix, titratable acid, pH and tannins, and fruit of 9 cider apple varieties was harvested for cider making.

In 2007 a preliminary trial to test the possible use of a mechanical raspberry harvester to pick cider apples was conducted in Block 2 of the WSU Mount Vernon NWREC orchard. Trees are planted at close intervals, on strongly dwarfing rootstocks M27 and EMLA 9, and trained to a low trellis. The equipment used was a Littau Model OR0012 raspberry picker, with adjusted beater action and ground speed. In 2011 we conducted a replicated trial with this equipment, comparing plots harvested by machine to hand harvested plots. Data was recorded per plot for time of picking, number of pickers, amount harvested, postharvest groundfalls, and total yield. After the harvest, spur and limb damage was inspected visually and counted per plot, and fruit damage was assessed by selecting 100 fruit at random from each plot and recording the number of fruit bruised, cut, and split (half). At harvest, two boxes of fruit from each plot were randomly selected and pressed. One box was pressed immediately post harvest and the other was pressed after 2 weeks in cold (32°F) storage; the resulting juice samples were analyzed for °Brix, pH, titratable malic acid, and percent tannins.

RESULTS AND DISCUSSION:

Objective 1. To evaluate hard cider apple varieties and determine productivity (fruit yield and quality) in northwest Washington.

The weather pattern in early 2011 was unusually cool, with daily mean temperature in the range of 35°F to 45°F recorded January through March, and a low of 19°F on February 25 (source: AgWeatherNet). All varieties bloomed much later than normal, with full bloom from May 13 to June 13 (Table 1). Observations made of bloom dates and bloom density from 2000 to 2011 indicate that some varieties bloom abundantly each year, while others appear to have a tendency to alternate bearing (Table 2). Varieties with a record of alternate bearing need a pruning and thinning regime that can reduce that tendency. Early blooming varieties such as Granniwinkle, Jouveaux, and Golden Russet are of special interest as their early bloom date makes them less susceptible to fire blight (*Erwinia amylovora*) infection. This is of particular importance in areas such as Central and Eastern Washington where that disease is problematic. This problem is not seen currently in western Washington; however, since most cider varieties bloom later than dessert apples it is important to be sure that late blooming varieties have a pollination source available (usually other cider apples).

In 2011 productivity was above average to high in almost all varieties, and samples were collected from several varieties that in previous years had insufficient fruit. Harvested fruit was processed, and fruit juice analyzed for °Brix, pH, titratable malic acid, and percent tannins (Table 3; Figures 1, 2, 3, and 4). All varieties have a place in cider making; the key for cider makers is

in understanding the qualities and attributes of each variety in order to determine its best use for their purposes. Depending on the desired cider style, some varieties are better suited to make single variety ciders, and others have specific characteristics that combine with other varieties in a blend. Varieties with higher tannins tend to impart more body and viscosity to ciders when blended with standard dessert apples. Varieties with lower tannins, such as standard dessert apples, can be used in producing sparkling ciders.

Bottling of 2 cider apples (Campfield, Mettais) harvested in 2010 was done in January 2011 and will be evaluated in 2012. The cooperator, Drew Zimmerman, will coordinate the evaluations which will be done by selected panelists trained in sensory evaluation of hard cider using established evaluation criteria (Mitchell). Nine varieties, most of which have not yet been evaluated for cider, were harvested for cider making in 2011 (Blanc Mollet, Chisel Jersey, Golden Russet, Harrison, Hewlett Crab, Major, Mettais, Medaille D'Or, Zabergau Reinette); they will be bottled Spring 2012.

An unanticipated outcome of this study is that following discussion with cooperator Drew Zimmerman, we have determined that the trees grown as 'Tramlett's Bitter' at WSU Mount Vernon NWREC as well as other locations in the Pacific Northwest do not fit descriptions of that variety from England. We are taking steps to determine the true identity of this variety, as it has been a good producer and worth propagating under its proper name.

Objective 2. Mechanical harvest trial.

Results of the mechanical harvest trial indicate that hand harvest required 8 times more hours per hectare than machine harvest, a cost difference of approximately \$260 per hectare, assuming \$10-\$12 per hour for labor plus labor taxes and benefits (Table 4). This cost comparison includes all hand picking for removing fruit and groundfalls in the machine harvested plots. Harvest efficiency for mechanical harvest (not including hand harvest cleanup) was 77% as compared with hand harvest (Table 5). Hand cleanup after mechanical harvest accounted for an additional 23% of yield. Total harvest efficiency including hand cleanup was 89% for the mechanical harvester as compared with hand harvest. Thus, mechanical harvesting is a major saving of time and labor in harvesting cider apples, but results in approximately 10% yield loss.

Damage to limbs and spurs was not significantly different due to harvest method, though damage due to machine harvest was slightly greater (Table 6). Some changes in the trellis training, such as removing limbs too low for the machine to pick up, promoting development of shorter fruit bearing limbs at right angles to the row, and looser tying of upright branches to wires allowing for greater flexibility might reduce the amount of groundfalls and of fruit left on the trees that must be "cleaned up" by hand picking. Use of ethrel or other spray materials to manage harvest timing might also be worth future study. It is notable that all sample fruit was bruised in both harvest methods, but only mechanically harvested fruit were cut or split.

Damaged fruit could be a serious issue where harvested fruit is stored before pressing for any length of time due to potential rot from damaged fruit. In this study no increased rot was observed in stored fruit, and the only significant difference in juice analysis between samples pressed immediately after harvest and samples pressed after 3 weeks in storage was the higher

°Brix (Table 7). Fruit that was stored for 3 weeks had higher °Brix than freshly harvested fruit, likely due to further conversion of starches to sugar in the fruit during storage.

Outreach and Education

Annual reports, including bloom data and juice analysis were made public through the Hard Cider web page <http://extension.wsu.edu/maritimefruit/Pages/Cider.aspx> for all varieties fruiting at WSU Mount Vernon NWREC. The website also provides information on events such as cider classes and workshops, and reference links to outside sources of information on hard cider orcharding and production.

Extension Manual PNW621 “*Hard Cider Production and Orchard Management in the Pacific Northwest*” (48 pp.) was published in November 2010, summarizing the last 15 years of research in hard cider varieties and cider making at WSU Mount Vernon NWREC. It contains information on cider making and variety analysis useful both for beginning and more experienced cider makers. As of January 2012, 671 copies of this manual had been sold and distributed, and the manual is now in its third printing.

Cider School courses at WSU Mount Vernon NWREC were conducted in 2011 by the Northwest Agriculture Business Center of Mount Vernon, consisting of introductory courses June 27-July 1 and December 12-16, 2011. A one-day workshop on cider apple orchards taught by Gary Moulton was held at WSU Mount Vernon NWREC on June 25 and repeated December 10, 2011; he also gave a one-day workshop on April 23 at Ed’s Apples in Sultan, WA, “Hard Cider Making and Orcharding,” sponsored by WSU Snohomish County Extension.

Over the years, our research has provided growers with information on the characteristics of apple varieties selected for hard cider production. Currently, 10 commercial cideries have been established in Washington State, as well as one or two in Oregon and British Columbia, by participants in our workshops. The workshops continue to be well attended, and our information, both in print and online, is widely disseminated.

ACKNOWLEDGEMENTS

Support for this project from the Washington State Department of Agriculture, the Washington Wine Advisory Board and the Northwest Cider Association is gratefully acknowledged.

OUTSIDE PRESENTATIONS OF RESEARCH:

Moulton, G.A., 2011. Principles and Practices of Cider Making: Orchard Technology in Hard Cider Production. Cider School class and field demonstration, WSU Mount Vernon NWREC, Mount Vernon WA, December 13, 2011.

Moulton, G.A., 2011. Workshop presentation, “Orchard Management: Cider Fruit Production.” WSU Mount Vernon NWREC, Mount Vernon WA, December 10, 2011.

Moulton, G.A., 2011. Principles and Practice of Cider Making: Orchard Technology in Hard Cider Production. Cider School class and field demonstration, WSU Mount Vernon NWREC, Mount Vernon WA, June 28, 2011.

Moulton, G.A., 2011. Workshop presentation, "Orchard Management: Cider Fruit Production."
WSU Mount Vernon NWREC, Mount Vernon WA, June 25, 2011.
Moulton, G.A., 2011. Pomology Workshop Series, "Hard Cider Making and Orchardling"
Snohomish County Extension Field Day, Sultan, WA, April 23, 2011.

FUND STATUS

Wine Advisory Board, Washington State Department of Agriculture - \$ 2,000

Table 1. Mean date of full bloom in cider apple varieties observed at WSU Mount Vernon NWREC, 2000-2011, listed in order from mean earliest to latest bloomers¹ (data not collected 2005 and 2006; all varieties were not available for observation in all years).

Variety	Mean	11	10	09	08	07	04	03	02	01	00
Gravenstein ¹	4/27	5/13	4/11								
Ross Nonpareil	4/30	5/14	4/15								
Golden Russet	5/2	5/13	4/15	5/13	5/10	4/30	4/14	5/6			5/10
Roxbury Russet	5/2	5/14	4/17	5/7	5/10	4/28	4/16	5/6	5/15	5/2	5/10
Granniwinkle	5/3	5/13	4/15	5/7	5/5						5/5
Jouveaux	5/3	5/13	4/15	5/7	5/7						5/7
Maude	5/3	5/14	4/19	5/7							
Jonagold ¹	5/3	5/20	4/15								
Grimes Golden	5/4	5/13	4/21	5/7							
Grindstone	5/4	5/15	4/17	5/7	5/7						5/7
Fillbarrel	5/5		4/26	5/13							
Track Zero (Ross Sdlg)	5/5	5/20	4/22	5/7	5/9	4/28					5/9
Reine des Pommes	5/7			5/13		5/7	4/23	5/13			
Vagner Ascher	5/7	5/20	4/17	5/13							
Tom Putt	5/7	5/20	4/26	5/13	5/16	5/7	4/23	5/13			5/16
Smith's Cider	5/7	5/20	4/22	5/9							
Zabergau Reinette	5/8	5/20	4/18	5/7	5/16						5/16
Foxwhelp	5/8					5/7	4/23	5/13	5/15	5/9	
Campfield	5/8	5/20	4/22	5/13							
Cap of Liberty	5/8	5/20	4/22	5/7	5/16	5/7					5/16
Redstreak	5/9	5/20	4/29	5/13	5/16	5/7	4/26				5/16
Finkenwerder Herbstprinz	5/10	5/20	4/22	5/13	5/18	5/7					5/18
Bramley's Seedling	5/10	5/20		5/13	5/16	5/7	4/23	5/11			5/16
Bulmer's Norman	5/10	5/20	4/27	5/13	5/16	5/7	4/28	5/19			5/16
Tremlett's Bitter ²	5/10	5/25	4/27	5/7	5/16	5/7					5/16
Amere de Berthcourt	5/11	5/25	4/22	5/15							
Harrison	5/11	5/20	4/23	5/13	5/18						5/18
Frequin Rouge	5/11	5/20	5/7	5/7	5/16	5/7					5/16
Bouteville	5/13	5/20		5/7	5/13						5/13
Reine des Hatives	5/13	5/20	5/7	5/13	5/18	5/5					5/18
Sweet Alford	5/13	5/17		5/7	5/16						5/16
Muscadet de Dieppe	5/13	5/20		5/13	5/18	5/7	4/28	5/13	5/21	5/16	5/18
Brown's Apple	5/14	6/1					4/23	5/13	5/15	5/16	
Michelin	5/14	5/31	5/7	5/15	5/18	5/7	4/25	5/13	5/21	5/16	5/18
Taylor's	5/14	5/20		5/13						5/11	
Crow Egg	5/14	5/20		5/7	5/16						5/16
Whidbey	5/14	5/20	5/7	5/13	5/16						5/16
Metais	5/14	5/31	4/29	5/13							
Kingston Black	5/15	5/31	5/7	5/19	5/25	5/7	4/25	5/13	5/21		5/25
Bramtot	5/16	5/27	5/7	5/13							
Doux Normandie	5/16	5/27	5/7	5/13							
Taliaferro	5/16	5/20		5/13	5/16						5/16
Muscat de Bernay	5/17	5/27		5/7							
Yarlington Mill	5/17	5/31	4/29	5/13	5/18	5/15	4/30	5/19	5/21	5/19	5/18

Kermerrien	5/18	6/1	5/13	5/13	5/16	5/15					5/16
Peau de Vache	5/19	5/31	5/7	5/19	5/18						5/18
Chisel Jersey	5/19	6/8		5/19	5/18	5/15	4/30	5/19	5/21	5/19	5/18
Frequin Audievre	5/19			5/19							
Frequin Tardif	5/19			5/19							
Harry Masters' Jersey	5/20	6/1		5/19	5/30	5/15	5/3	5/19	5/21	5/19	5/30
Dabinett	5/20	6/3	5/25	5/19	5/25	5/17	5/3	5/22	5/21	5/17	5/25
Blanc Mollet	5/20	5/20		5/19							
Lambrooke Pippin	5/20	5/20	5/3	5/19							
Stembridge Jersey	5/22	6/1	5/20	5/13							
Major	5/22	6/1		5/19	5/16						5/16
Coat Jersey	5/23	6/1		5/19	5/18						5/18
Brown Snout	5/24	6/3		5/27		5/22	5/4	5/22	5/31	5/29	
Red Jersey	5/25				5/25						5/25
Cort Pendu Plat	5/25		5/27	5/19	5/30						5/30
Sweet Coppin	5/26	6/1		5/19							
Vilberie	5/26	6/10		5/27	5/30	5/22	5/4	5/22	5/31	5/29	5/30
Breakwell Seedling	5/26	6/3	5/27	5/27	5/22	5/22					5/22
American Forestier	5/27	6/3		5/19							
Brown Thorn	5/27	6/3		5/19							
Cort Pendu Rose	5/28	6/3		5/19	5/30						5/30
Royal Jersey	5/29	6/5		5/21							
Stoke Red	5/31	6/3	5/27								
Cimitiere	6/1	6/8		5/27	5/30						5/30
Medaille D'Or	6/6	6/13		5/29							

¹Bloom dates of 2 dessert apples (Gravenstein and Jonagold) were recorded for comparison in 2010 and 2011.

²In 2011 it was determined that the trees grown as 'Tramlett's Bitter' at WSU Mount Vernon NWREC as well as other locations do not fit descriptions of that variety from England.

Table 2. Mean bloom density¹ of cider apple varieties observed at WSU Mount Vernon NWREC, 2000-2011, listed in descending order (data not collected 2005 and 2006; all varieties were not available for observation in all years).

Variety ²	Mean	2011	2010	2009	2008	2007	2004	2003	2002	2001	2000
Granniwinkle	5.0	5	5	5	5						
Jouveaux	5.0	5	5	5	5						
Ross Nonpareil	5.0	5	5								
Doux Normandie	4.8	5	5	4.5							
Jonagold ²	4.8	4.5	5								
Bramtot	4.7	5	4	5							
Grimes Golden	4.7	5	5	4							
Mettais	4.7	5	4	5							
Vagner Ascher	4.7	5	5	4							
Bulmer's Norman	4.6	5	5	5	5	5	3.5	4			
Golden Russet	4.6	5	5	5	5	5	4	3			
Fillbarrel	4.5		5	4							
Maude	4.5	4.5	5	4							
Peau de Vache	4.5	4	5	4	5						
Gravenstein ²	4.5	4	5								
Frequin Rouge	4.4	5	4.5	3.5	4	5					
Michelin	4.4	5	5	5	3.5	5	2.5	5	3.5	5	
Tom Putt	4.3	5	5	5	3.5	5	4	2.5			
Brown Snout	4.2	5		5		4	4	4	3.5	4	
Campfield	4.2	4	5	3.5							
Tremlett's Bitter ³	4.2	5	4	3.5	3.5	5					
Cap of Liberty	4.0	5	2	5	3	5					
Medaille D'Or	4.0	4									
Harrison	3.9	4.5	4	4	3						
Zabergau Reinette	3.9	5	3	4.5	3						
Brown's Apple	3.8	4					3.5	3.5	4.5	3.5	
Stembridge Jersey	3.8	4.5	3	4							
Smith's Cider	3.7	5	1	5							
Breakwell Seedling	3.6	5	4		5	4					
Finkenwerder Herbstprinz	3.6	3.5	4	4	3	3.5					
Harry Masters' Jersey	3.6	5		4	2.5	5	3	3	3	3.5	
Track Zero (Ross Sdlg)	3.6	4	1	5	3	5					
Yarlington Mill	3.6	3	4.5	1.5	4.5	2	4.5	4	4	4	4
Bouteville	3.5	5		5	4						
Redstreak	3.5	3	4	3.5	4	3.5	3				
Taylor's	3.5	4.5		5						4	4
Kingston Black	3.4	5	2.5	4.5	2.5	5	2	4	2		
Roxbury Russet	3.4	4	3	3.5	4	4	3	3	3	3	3
American Forestier	3.3	5		5							
Chisel Jersey	3.3	4		5	5	4	3	3.5	3.5	2	
Foxwhelp	3.3					5	3	3.5	5	3	4
Kermerrien	3.3	3	1	5	2.5	5					
Lambrooke Pippin	3.3	5	3	2							
Muscat de Bernay	3.2	4.5		5							
Amere de Berthcourt	3.0	5	2	4	1						
Blanc Mollet	3.0	4		5							

Cimitiere	3.0	5		5	2						
Cort Pendu Plat	3.0		2	4	3						
Crow Egg	3.0	5		5	2						
Dabinett	3.0	5	1	4.5	2.5	5	3	3	3	3	
Muscadet de Dieppe	3.0	3		3	4	2.5	4	2.5	3.5	3	4
Sweet Coppin	3.0	5		4							
Major	2.9	4.5		5	2						
Reine des Pommes	2.9			5	0	5	2.5	5			
Vilberie	2.9	5			3	3.5	3	2.5	3	3	
Whidbey	2.9	4.5	2	3	2						
Bramley's Seedling	2.8	4	1	3.5	2	3	2	4			
Cort Pendu Rose	2.8	4		4	3						
Sweet Alford	2.8	5		4	2						
Brown Thorn	2.7	5		3							
Royal Jersey	2.7	4		4							
Coat Jersey	2.5	5		4	1						
Frequin Audievre	2.5			5							
Stoke Red	2.5	4	1								
Grindstone	2.4	2	3	2.5	2						
Taliaferro	2.0	3		3	2						
Reine des Hatives	1.9	2	2	1.5	2	2					
Red Jersey	1.7	5		1	4						

¹Abundance rating:

1= Very few blooms

2= Light bloom, below needed amount to set commercial crop

3= Normal bloom, sufficient to set commercial crop

4= Abundant bloom, between normal and snowball- thinning may be required

5= Snowball bloom, very abundant, may cause alternate bearing if not thinned early

²Bloom density of 2 dessert apples (Gravenstein and Jonagold) were recorded for comparison in 2010 and 2011.

³In 2011 it was determined that the trees grown as 'Tramlett's Bitter' at WSU Mount Vernon NWREC as well as other locations do not fit descriptions of that variety from England.

Table 3. Percent tannin, brix, pH and titratable malic acid in juice of apples grown and tested at WSU Mount Vernon NWREC in 2008 – 2011.

Sample	Tannin %				Brix				pH				Malic Acid g/L			
	2011	2010	2009	2008	2011	2010	2009	2008	2011	2010	2009	2008	2011	2010	2009	2008
Amere de Berthcourt	0.28	0.48	0.68	DNF ¹	11.1	13.5	14.0	DNF	4.23	4.23	4.47	DNF	1.29	2.14	2.26	DNF
American Forestier	0.20	- ²	0.19	-	11.6	-	11.8	-	4.09	-	3.63	-	1.98	-	1.98	-
Bedan de Parts	0.21				12.8				4.21				1.93			
Blanc Mollet	0.22	-	0.30	-	11.5	-	11.4	-	4.19	-	4.27	-	1.50	-	1.50	-
Bouteville	0.17	-	0.16	-	12.7	-	12.0	-	4.56	-	4.43	-	1.07	-	1.17	-
Bramley's Seedling	0.09	DNF	0.16	0.11	10.6	DNF	10.0	12.8	2.79	DNF	3.63	3.35	9.75	DNF	10.18	10.29
Bramtot	0.88	0.56	-	-	13.8	14.3	-	-	3.94	4.15	-	-	2.79	2.95	-	-
Breakwell Seedling	0.16	0.64	0.32	0.12	9.6	12.0	11.0	10.4	3.09	3.18	3.17	3.43	6.59	13.56	5.36	6.97
Brown Snout	0.16	0.20	0.26	0.08	11.4	12.0	12.0	13.0	3.72	3.77	3.73	4.10	2.20	2.95	3.00	2.95
Brown Thorn	0.14				10.5				4.18				1.23			
Brown's Apple	0.08				9.0				3.00				7.61			
Bulmer's Norman	0.19	-	0.25	0.17	10.5	-	11.2	11.8	3.98	-	3.94	4.06	2.14	-	1.88	1.77
Campfield	0.36	0.19	0.27	-	11.2	13.2	13.0	-	4.26	4.46	4.63	-	2.30	2.73	2.63	-
Cap O'Liberty	0.21	DNF	0.26	0.18	11.7	DNF	11.0	12.0	3.36	DNF	2.89	3.38	10.18	DNF	9.87	13.67
Chisel Jersey	0.32	1.00	0.43	-	13.0	15.6	14.2	-	4.04	4.49	4.93	-	2.25	3.38	1.88	-
Cimitiere	0.31	-	0.33	-	8.5	-	11.2	-	4.27	-	4.90	-	1.13	-	1.39	-
Coat Jersey	-	-	0.48	-	-	-	11.8	-	-	-	3.72	-	-	-	1.93	-
Court Pendu Plat	-	DNF	0.10	-	-	DNF	13.0	-	-	DNF	2.93	-	-	DNF	7.72	-
Court Pendu Rose	0.13	0.14	-	-	10.3	13.2	-	-	3.17	3.75	-	-	6.51	6.70	-	-
Crow Egg	0.10	-	0.10	0.10	10.6	-	10.2	14.0	3.79	-	4.01	3.66	3.22	-	3.27	5.63
Dabinett	0.17	0.69	0.32	0.23	12.4	14.9	14.0	14.2	4.25	4.38	4.90	4.47	8.52	2.57	1.34	1.93
Domaines	-	-	0.52	0.24	-	-	15.0	16.0	-	-	4.53	4.16	-	-	2.09	2.79
Doux Normandie	-	0.27	0.48	-	-	11.0	13.0	-	-	4.02	3.58	-	-	3.27	3.86	-
Dymock Red	-	-	0.21	0.19	-	-	13.0	14.4	-	-	4.07	4.29	-	-	1.82	2.03
Finkenwerder Herbstprinz	0.10	0.06	0.15	0.06	13.8	12.9	14.6	14.0	3.15	3.23	2.96	3.44	8.52	9.27	11.36	10.13
Foxwhelp	0.17	-	0.33	-	11.8	-	14.0	-	3.04	-	3.01	-	7.34	-	10.18	-
Frequin Audievre	-	-	0.23	-	-	-	12.0	-	-	-	4.75	-	-	-	1.40	-
Frequin Rouge	0.29	DNF	0.57	0.19	11.2	DNF	12.2	10.8	3.92	DNF	4.57	4.20	2.25	DNF	2.58	2.73
Frequin Tardif	-	-	0.28	-	-	-	12.0	-	-	-	4.36	-	-	-	2.58	-
Freyberg ³	-	-	-	0.01	-	-	-	14.0	-	-	-	3.96	-	-	-	3.48
Golden Russet	0.19	-	0.18	0.10	17.6	-	15.0	18.0	3.88	-	3.93	3.72	5.47	-	7.93	6.38
Granniwinkle	0.13	-	0.10	0.05	10.8	-	10.4	12.0	4.23	-	1.58	3.80	1.88	-	1.82	3.48
Grimes Golden	0.07	0.06	-	-	13.2	12.0	-	-	3.32	3.43	-	-	6.32	6.54	-	-
Grindstone	0.17	DNF	0.15	-	13.8	DNF	11.4	-	3.51	DNF	3.18	-	6.16	DNF	5.25	-
Harrison	0.15	0.14	0.19	-	15.7	15.6	16.0	-	3.47	3.69	2.94	-	4.98	8.25	10.08	-
Harry Masters' Jersey	0.18	-	0.30	DNF	10.5	-	12.0	DNF	4.30	-	4.18	DNF	1.55	-	1.72	DNF

	2011	2010	2009	2008	2011	2010	2009	2008	2011	2010	2009	2008	2011	2010	2009	2008
Hewes Crab	0.29	0.32	-	-	15.0	15.0	-	-	3.13	3.29	-	-	7.84	10.66	-	-
Jouveaux	0.27	-	-	-	9.9	-	-	-	3.97	-	-	-	1.61	-	-	-
Kermerrien	0.28	0.48	0.46	0.34	11.2	13.2	12.8	14.0	3.79	3.82	3.86	4.00	2.30	2.54	2.47	2.23
Kingston Black	0.11	0.37	0.26	0.13	11.8	16.0	13.4	13.0	3.27	3.66	3.22	3.70	5.52	8.52	5.63	5.90
Lambrooke Pippin	0.31	-	0.51	-	12.3	-	14.4	-	3.20	-	2.86	-	7.40	-	10.61	-
Major	0.23	-	0.29	0.22	13.0	-	13.4	14.8	4.13	-	4.24	4.42	1.77	-	1.82	1.82
Marie Menard	-	0.35	-	-	-	13.6	-	-	-	4.41	-	-	-	2.03	-	-
Marin Oufroy	-	0.32	0.24	-	-	16.6	14.2	-	-	4.57	4.47	-	-	3.00	2.84	-
Maude	0.11	DNF	0.10	-	12.3	DNF	12.0	-	3.40	DNF	3.40	-	4.66	DNF	4.82	-
Medaille D'Or	0.69	1.02	1.75	- ¹	14.7	14.0	17.2	-	4.18	4.26	4.37	-	2.84	3.32	3.54	-
Mettais	0.26	0.51	0.30	-	12.9	15.8	12.0	-	4.32	4.40	4.33	-	1.93	3.20	1.29	-
Michelin	0.14	0.26	-	-	11.3	12.8	-	-	3.88	4.11	-	-	2.41	3.10	-	-
Mott Pink ³	0.05	-	0.11	-	9.0	-	12.0	-	3.30	-	3.16	-	4.45	-	7.08	-
Musc.t de Dieppe	0.17	DNF	0.24	DNF	14.3	DNF	14.0	DNF	4.48	DNF	3.84	DNF	1.82	DNF	2.30	DNF
Muscat de Berney	-	-	0.32	-	-	-	12.0	-	-	-	3.68	-	-	-	2.57	-
Nehou	0.40	-	0.61	0.22	16.5	-	14.2	15.0	3.96	-	4.56	4.01	2.73	-	3.10	3.81
Peau de Vache	0.17	DNF	0.19	0.09	10.7	DNF	11.0	12.4	4.18	DNF	3.71	4.08	1.93	DNF	3.00	2.52
Red Jersey	-	DNF	DNF	0.26	-	DNF	DNF	11.0	-	DNF	DNF	4.38	-	DNF	DNF	1.72
Redstreak	0.09	DNF	0.15	0.06	11.2	DNF	12.0	12.0	3.08	DNF	2.99	3.36	8.84	DNF	8.74	9.86
Reine des Hatives	0.42	-	DNF	0.10	11.5	-	DNF	14.0	3.00	-	DNF	4.34	9.11	-	DNF	2.47
Reine des Pommes	-	DNF	0.67	DNF	-	DNF	14.9	DNF	-	DNF	4.21	DNF	-	DNF	3.38	DNF
Ribston Pippin	-	0.26	DNF	0.11	-	17.6	DNF	14.8	-	3.77	DNF	3.48	-	4.80	DNF	6.54
Ross Nonpareil	0.50	-	-	-	16.1	-	-	-	3.82	-	-	-	3.48	-	-	-
Roxbury Russet	0.08	DNF	0.11	0.07	14.4	DNF	16.4	17.0	3.73	DNF	3.31	3.85	4.23	DNF	4.77	5.41
Royal Jersey	0.54	-	0.45	DNF	12.5	-	12.2	DNF	4.03	-	4.13	DNF	1.88	-	1.50	DNF
Smith's Cider	0.08	DNF	0.12	-	11.7	DNF	11.0	-	3.64	DNF	3.15	-	4.30	DNF	4.28	-
Stembridge Jersey	0.32	-	0.48	-	9.4	-	12.9	-	4.00	-	4.69	-	1.66	-	2.41	-
Stoke Red	0.24	-	0.43	0.30	10.6	-	13.2	13.0	3.46	-	4.04	3.50	4.66	-	6.22	7.50
Sweet Alford	0.10	-	0.15	0.06	10.1	-	11.0	14.6	4.20	-	4.77	4.32	1.34	-	1.34	2.89
Sweet Coppin	0.13	-	-	-	11.3	-	-	-	3.92	-	-	-	2.20	-	-	-
Taliaferro	0.09	-	0.19	-	11.1	-	10.2	-	3.25	-	2.87	-	6.73	-	6.81	-
Taylor's	0.12	-	-	-	12.3	-	-	-	4.36	-	-	-	1.50	-	-	-
Tom Putt	0.10	0.22	0.16	0.08	10.7	11.8	11.0	11.2	3.14	3.37	3.77	3.52	6.51	6.54	6.27	7.24
Track Zero (Ross)	0.13	DNF	0.17	-	13.1	DNF	12.0	-	4.10	DNF	3.97	-	1.66	DNF	1.61	-
Tramlett's Bitter	0.16	-	0.28	0.17	10.1	-	11.8	12.2	3.06	-	2.88	3.44	9.92	-	9.86	10.34
Vilberie	0.43	0.58	0.91	0.41	9.3	11.5	12.0	14.2	3.80	4.13	3.60	3.89	1.82	2.57	3.43	3.86
Whidbey	0.16	DNF	0.15	0.07	10.6	DNF	11.9	14.4	3.67	DNF	3.96	3.53	3.75	DNF	4.88	8.30
Yarlington Mill	0.22	0.29	0.38	0.11	12.6	14.0	14.0	11.0	3.76	3.97	4.97	4.04	1.88	2.73	1.72	2.68
Zabergau Reinette	0.12	DNF	0.16	0.10	13.6	DNF	11.9	16.4	3.45	DNF	3.85	3.66	5.09	DNF	6.27	8.95

¹DNF = Did not fruit, mature tree in alternate year;

²Blank (-) indicates data not collected (young trees, dessert apples tested only once, etc.)

³dessert apple

Table 4. Picking times recorded in mechanical harvest study October 25, 2011 at WSU Mount Vernon NWREC.

Harvest Type	Plot pick time (minutes)	Total plot man hours (minutes)	Hours/hectare per person
Hand	10.62 a	50.35 a	93.25 a
Machine	2.00 b	6.00 b	11.50 b
<i>Significance</i>	<i>0.0002</i>	<i>0.0002</i>	<i>0.0002</i>

Table 5. Harvest yield recorded in mechanical harvest study October 25, 2011 at WSU Mount Vernon NWREC.

Harvest Type	Fruit Weight (kg)				Harvest efficiency (%) ¹
	Post harvest groundfall	Harvest	Post harvest hand cleanup	Total Harvest	
Hand	0.00 b	118.97	0	118.97	100 a
Machine	12.07 a	81.23	12.46	105.76	77 b
<i>Significance</i>	<i>0.0015</i>	<i>0.0908</i>	<i>0.0621</i>		<i>0.0012</i>

¹Picker efficiency for the machine harvest plots includes fruit picked by machine harvester but not the groundfalls or hand “cleanup.”

Table 6. Fruit and tree damage recorded in mechanical harvest study October 25, 2011 at WSU Mount Vernon NWREC (spur and limb damage counted lesions per plot).

Harvest Type	Spur damage	Limb damage	Per 100 fruit sample		
			Bruise %	Number cut	Number cut in half
Hand	1.250	0.125	100	0.00 b	0.00 b
Machine	2.375	0.625	100	11.75 a	4.50 a
<i>Significance</i>	<i>0.3082</i>	<i>0.2266</i>	<i>1.000</i>	<i>0.0055</i>	<i>0.024</i>

Table 7. Cider apple juice characteristics of fruit mechanically harvested October 25, 2011 at WSU Mount Vernon NWREC.

Crush Date	°Brix	pH	Spec. Gravity	Malic Acid	Tannin
At harvest	10.88 b	3.823	1.0434	2.2163	0.4850
After 3 weeks	12.05 a	3.8113	1.0486	2.3363	0.1488
<i>Significance</i>	<i>0.0006</i>	<i>0.6022</i>	<i>0.0003</i>	<i>0.1778</i>	<i>0.2283</i>

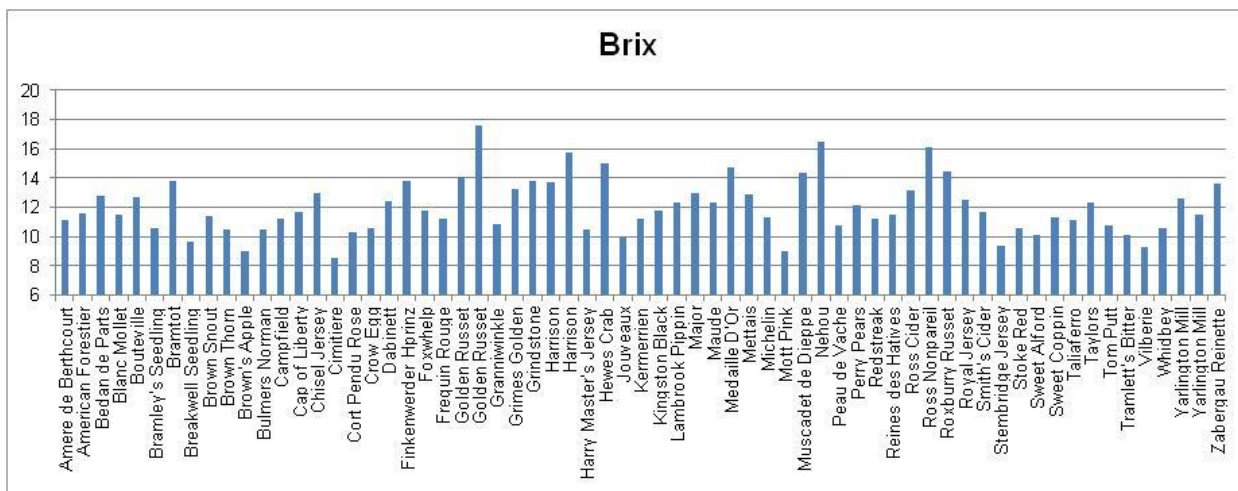


Figure 1. Brix (degrees) of juice from cider varieties tested at WSU Mount Vernon NWREC in 2011.

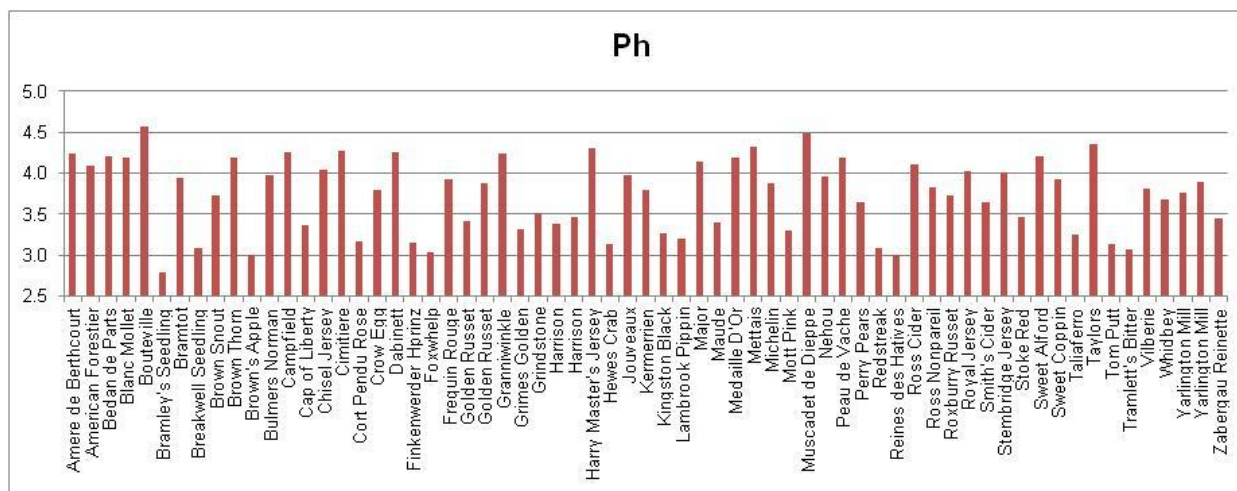


Figure 2. Measured pH of juice from cider varieties tested at WSU Mount Vernon NWREC in 2011.

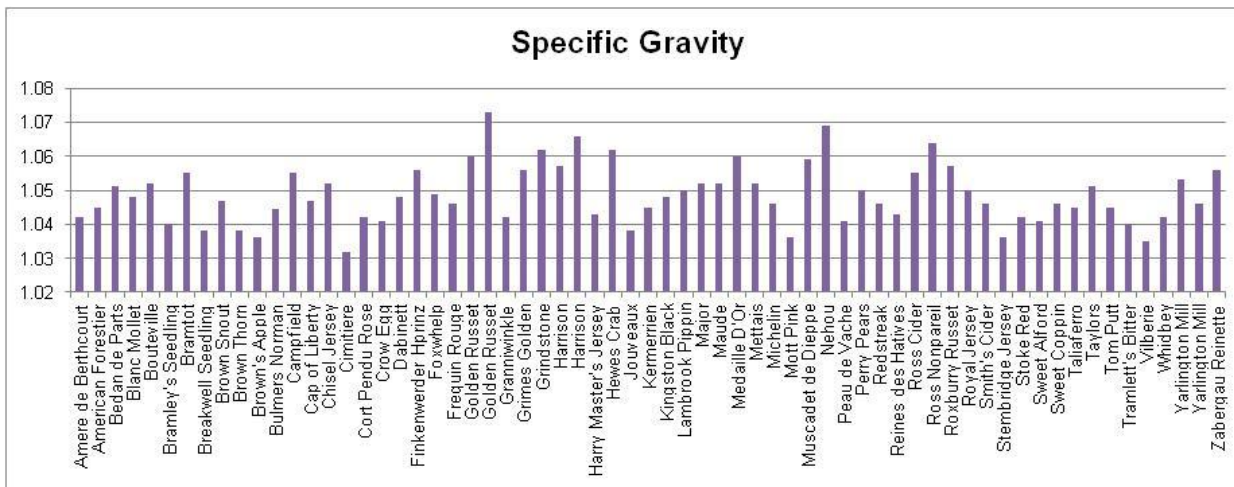


Figure 3. Specific gravity of juice from cider varieties tested at WSU Mount Vernon NWREC in 2011.

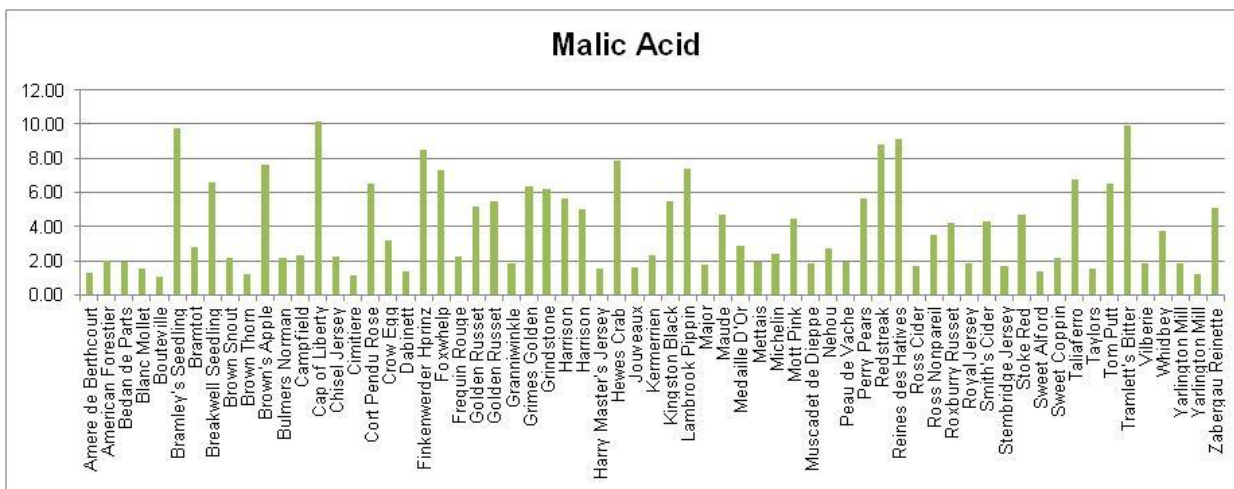


Figure 4. Titratable malic acid of juice from cider varieties tested at WSU Mount Vernon NWREC in 2011.

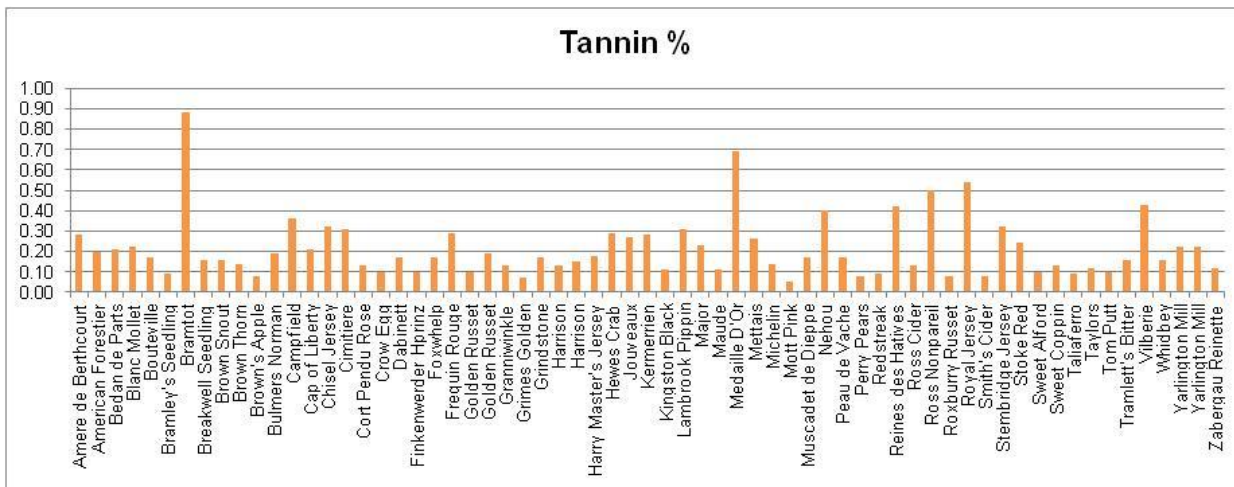


Figure 5. Percent tannin of juice from cider varieties tested at WSU Mount Vernon NWREC in 2011

