Variety Trials

Evaluation of Peach Cultivars in Cool, Mesic Ullensvang, Norway

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SUMMARY. In a cool, maritime Nordic climate, where fruit have been grown for many centuries, 13 early maturing peach (*Prunus persica*) cultivars from northern European climates were evaluated over a 6-year period. Peach leaf curl (*Taphrina deformans*) was the main disease affecting production. The most consistent yielding cultivar was Riga with 5.74 kg/tree in 2009, 2.06 kg/tree in 2010, and 4.71 kg/tree in 2011. Harnas yielded 6.93 kg/tree in 2010, but had very low yields in 2009 and no yield at all in 2011. 'Harnas' fruit quality was excellent when compared with all other cultivars, but trees were extremely susceptible to peach leaf curl. 'Riga' was somewhat tolerant of peach leaf curl but flowered early. We conclude that none of the cultivars tested are suitable for commercial production. However, looking forward, both 'Riga' and 'Harnas' may be suitable for commercial tunnel production and home gardens. Furthermore, 'Harnas' and 'Riga' could be considered for use in future breeding programs for this cool, mesic Nordic climate.

The southern part of the Hardangerfjord, Norway (lat. 60°19'8.03"N, long. 6°39'14.31"E) is one of the most northerly tree fruit producing areas in the world. The fertile, arable soils have been cultivated for almost a millennium (Bleie, 1947). Because of the maritime influence of the fjord, which is warmed by the Gulf Stream (Durif et al., 2011), mild winters prevail within 300 m of the shoreline of the fjord. All these factors, combined with very long days in summer result in a mesic climate that is suitable for the production of tree

fruit. For many centuries, sweet cherries (*Prunus avium*) and apples (*Malus domestica*) have been produced in this region (Sekse, 2007), but these crops have a relatively high chilling requirement (800–1200 chill units) compared with peaches (≈350 chill units) (Westwood, 1993). Wurm et al. (2002) maintained that the limit for peach production is an average temperature of 8 °C per year and Öhlinger (2008) maintained that the average daily temperature in July should be ≥18 °C. In

contrast, Ullensvang has an average yearly temperature of about 6.8 °C and an average daily temperature of about 15 °C in July with average annual rainfall of 1350 mm per year. However, successful home garden cultivation of peaches in the neighboring southeastern region of Norway suggested that peaches might be a potential novel crop for the Hardanger region. Consequently, we decided to evaluate the potential for peaches in this region on a semicommercial basis at Bioforsk, Ullensvang. The objectives of this study were to develop expertise in cultivation and plant protection and to evaluate productivity, fruit quality, and storability of several peach cultivars.

Materials and methods

In Winter 2005, grafted trees of 13 early maturing, self-fertile peach cultivars (Table 1) all on 'St. Julien A' rootstock were imported from Denmark, England, The Netherlands, and Poland. At the time of planting, 'St. Julien A' was the most cold-tolerant rootstock being used in Europe (Andersen et al., 2006). Selection criteria for cultivars for this preliminary investigation of peach suitability in Norway included early maturity in fall, good winter freeze tolerance, and late blooming. In Spring 2006, trees were planted in a deep, sandy loam in a randomized complete block design with two trees per plot and four replicates at a spacing of 2.5 × 4 m (1000 trees/ha) and trained to a slender spindle. Subsequently, winter pruning was performed when the trees were dormant. Each year in early April, trees were fertilized with 11N–2.2P–15.9K at a rate of 500 kg·ha⁻¹ as a broadcast according to the principles described by Layne et al. (1996). In 2009, based on soil analysis, the orchard was limed with calcium hydroxide at a rate of 2000 kg·ha⁻¹.

Trees were drip irrigated when water deficits occurred. In spring and summer, when necessary, trees were

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
6.4516	inch ²	cm ²	0.1550
0.4536	lb	kg	2.2046
1.1209	lb/acre	kg·ha ⁻¹	0.8922
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

Table 1. Date of peak flowering (about 80% flowers open) of 13 early maturing peach cultivars between 2009 and 2011 together with corresponding daily maximum temperature and cumulative precipitation each day in Ullensvang, Norway.

Cultivar	2009			2010			2011		
	Date	Maximum temp (°C) ^z	Rainfall (mm) ^z	Date	Maximum temp (°C)	Rainfall (mm)	Date	Maximum temp (°C)	Rainfall (mm)
Riga	30 Apr.	18.3	0	17 May	11.1	2	6 May	10.4	0
Vaes Oogst	2 May	14.9	5.2	19 May	17.9	0	10 May	17	7.3
Peregrine	3 May	12.7	0	20 May	19.7	0.2	12 May	13.8	14.7
Amsden June	3 May	12.7	0	18 May	15.6	0	15 May	13.3	3.4
Amsden	3 May	12.7	0	19 May	17.9	0	12 May	13.8	14.7
Harnas	4 May	11.2	2.8	19 May	17.9	0	10 May	17	7.3
Charles Ingouf	4 May	11.2	2.8	21 May	19.7	0.2	15 May	9.3	12.4
Frost	5 May	10.8	11.5	21 May	21.4	0	13 May	14	3.6
Revita	5 May	10.8	11.5	23 May	15.7	1.7	16 May	14	0.5
Champion	6 May	10.1	8.5	23 May	15.7	1.7	15 May	9.3	12.4
Benedicte	8 May	10.1	8.5	21 May	21.4	0	14 May	13.3	3.4
Reliance	9 May	12.3	8	20 May	19.7	0.2	17 May	10.2	9.2
Redhaven	11 May	11.7	6.8	21 May	21.4	0	13 May	14	3.6

^z(1.8 × °C) + 32 = °F, 1 mm = 0.0394 inch.

sprayed according to pesticide labels with fungicides copper, dithianon and boscalid + pyraclostrobin for peach leaf curl, blossom blight and brown rot (both *Monilinia* sp.). Insecticidal sprays were not necessary throughout the duration of this trial. 'Riga' was hand thinned to 15 cm between the fruits in 2010. Some minor thinning adjustments were performed on 'Harnas' the same year. Absolute minimum temperatures during the dormant season between 2007 and 2012 were -6.7 °C (Jan. 2007), -7.2 °C (Mar. 2008), -9.5 °C (Dec. 2009), -13.1 °C (Jan. 2010), -10.4 °C (Feb. 2011), and -8.2 °C (Dec. 2012).

Date of peak flowering (≈80% of all flowers open), flowering intensity (1 to 9 scale, where 1 = no flowers and 9 = ≈50 flowers/m of shoot length), fruit set (scale of 1 to 9, where 1 = no fruit set and 9 = ≈35 fruit/m of shoot length) (Jackson and Looney, 1999) were recorded in 2009, 2010, and 2011 by the second author only, so as to ensure consistency of ratings. In addition, he recorded incidence of peach leaf curl (1 to 9 scale, where 1 = no peach leaf curl and 9 = 100% of leaves infected) in 2011. Fruit were harvested when ground color broke from light green to yellow (Taylor and Rushing, 2012). Trees were harvested one or two times depending on the crop load. In general, all trees were harvested between mid-August and the first week of September and total yield per tree recorded for each year. Annually, during the dormant season (mid-November), trunk diameter (centimeters) was measured for

each tree at a height of 25 cm above the graft union and from this individual trunk cross-sectional area [TCSA (square centimeters)] was calculated. Yield efficiency (kilograms per square centimeter per tree) was also calculated from the yield per tree as a function of the TCSA (square centimeters). At harvest, select fruit characteristics, including fruit diameter, soluble solids (percentage) using a handheld digital refractometer (Atago®, Tokyo, Japan), and stone-splitting (which resulted in fruit cracking at either the proximal or distal end of the fruit) were recorded. Data were evaluated using the statistical software (Genstat® 16; VSN International, Rothamsted, UK) testing for differences in means between cultivars within each year using a one-way analysis of variance. A multiple comparison of intensity of peach leaf curl (2011 only) (Table 2), average flowering intensity and fruit set (Table 3), and yield per tree (Table 4) was performed for all cultivars in 2009, 2010, and 2011 according to Tukey's test ($P \leq 0.05$).

Results and discussion

During the first four growing seasons, all trees remained healthy. In 2011, some of the cultivars showed tree decline symptoms, including branch dieback and tree death. In late Summer 2011, two 'Redhaven' trees and one each of 'Charles Ingouf' and 'Peregrine' died. Between 2006 and 2011 the incidence of peach leaf curl was high because of the prevailing cool, moist conditions during spring. Intensive fungicidal treatments in 2010

Table 2. Incidence of peach leaf curl of 13 early maturing peach cultivars in Ullensvang, Norway, in 2011.

Cultivar	Incidence of peach leaf curl (1–9 scale) ^z
Riga	2.50 ab ^y
Vaes Oogst	5.94 def
Peregrine	4.94 cde
Amsden June	1.84 a
Amsden	1.79 a
Harnas	7.06 df
Charles Ingouf	7.38 df
Frost	2.63 ab
Revita	2.06 ab
Champion	7.5 df
Benedicte	3.94 bc
Reliance	4.55 abcd
Redhaven	4.63 cde
SE	0.83

^z1 = no leaves infected, 9 = 100% leaves infected.

^yMeans followed by the same letter are not significantly different at $P \leq 0.05$ according to Tukey's test.

reduced the incidence of the disease. Full cover sprays of copper and dithianon were effective in controlling this disease; however, timing was critical and both a fall and an early spring application were required for suitable control. Where these were not performed in a timely manner, disease incidence was extremely high. In 2011, incidence of peach leaf curl was similarly low for 'Amsden' (1.79), 'Amsden June' (1.84), 'Revita' (2.06), 'Riga' (2.5), and 'Frost' (2.63), but extremely high for 'Reliance' (7.83), 'Champion' (7.5), and 'Charles Ingouf' (7.38). All other cultivars exhibited intermediate susceptibility to the disease (Table 2).

Table 3. Average flowering intensity and average fruit set of 13 early maturing peach cultivars in Ullensvang, Norway, between 2009 and 2011.

Cultivar	2009		2010		2011	
	Avg flowering intensity (1–9 scale) ^z	Avg fruit set (1–9 scale) ^y	Avg flowering intensity (1–9 scale)	Avg fruit set (1–9 scale)	Avg flowering intensity (1–9 scale)	Avg fruit set (1–9 scale)
Riga	7.88 d ^x	7.25 d	7.00 f	8.06 c	7.25 e	5.08 c
Vaes Oogst	6.13 cd	2.63 abc	5.00 d	1.56 a	3.36 bc	1.47 ab
Peregrine	5.75 bc	2.63 abc	4.88 d	1.94 a	2.79 ab	1.36 a
Amsden June	4.31 abc	1.88 ab	4.63 bcd	1.81 a	2.01 ab	1.15 a
Amsden	4.50 abc	2.25 abc	4.75 cd	2.25 a	1.50 a	1.25 a
Harnas	3.88 ab	3.00 abc	4.75 cd	5.88 b	3.17 ab	1.33 a
Charles Ingouf	4.88 abc	2.00 ab	4.00 ab	2.13 a	2.09 ab	1.10 a
Frost	5.81 bc	3.75 bc	4.13 abc	3.19 a	1.81 ab	1.19 a
Revita	5.06 abc	1.88 ab	4.50 bcd	3.13 a	4.63 cd	2.19 ab
Champion	5.13 abc	1.75 a	3.75 a	2.06 a	1.79 ab	1.15 a
Benedicte	4.25 abc	2.50 abc	4.00 ab	3.13 a	3.00 ab	2.38 ab
Reliance	7.99 d	3.95 c	6.00 e	2.43 a	5.00 d	2.67 b
Redhaven	3.38 a	2.25 abc	4.38 abcd	3.25 a	1.78 ab	2.17 ab
SE	0.58	0.55	0.21	0.60	0.47	0.38

^z1 = no flowers, 9 = about 50 flowers/m (15.2 flowers/ft) of shoot length.

^y1 = no fruit set, 9 = about 35 fruit/m (10.7 fruit/ft) of shoot length.

^xMeans followed by the same letter are not significantly different at $P \leq 0.05$ according to Tukey's test.

Table 4. Average annual yield of 13 early maturing peach cultivars in Ullensvang, Norway, between 2009 and 2011.

Cultivar	Avg annual yield (kg/tree) ^z		
	2009	2010	2011
Riga	5.74 b ^y	2.06 a	4.71 b
Vaes Oogst	0.64 a	0 a	0 a
Peregrine	0.26 a	0 a	0 a
Amsden June	0.13 a	0.18 a	0 a
Amsden	0.12 a	0.19 a	0 a
Harnas	1.33 a	6.93 b	0 a
Charles Ingouf	0.64 a	0.62 a	0 a
Frost	2.18 a	0.18 a	0 a
Revita	0.05 a	0.98 a	0 a
Champion	0.20 a	0.20 a	0 a
Benedicte	0.79 a	0.54 a	0 a
Reliance	0.52 a	1.26 a	0 a
Redhaven	0.22 a	0.57 a	0 a
SE	0.803	0.94	0.39

^z1 kg = 2.2046 lb.

^yMeans followed by the same letter are not significantly different ($P \leq 0.05$) according to Tukey's test.

In 2009, 'Riga' was the first cultivar to reach peak flowering on 30 April and 'Redhaven' was the last cultivar on 11 May (Table 1). Daily maximum temperatures ranged between 18.3 and 11.7 °C and the least rain fell between 30 April and 3 May. Rain on 2 May occurred during the night, whereas, most of the rain between 5 May and 8 May occurred during the daytime, which would most likely affect european honeybee (*Apis mellifera*) activity. Future research should record bee activity as a function of rainfall during sunlight hours. 'Riga' trees were the first to

flower [30 April (daily maximum 18.3 °C)] (Table 1); however, there is a risk associated with late spring frost. Furthermore, this cultivar had the highest fruit retention at harvest (5.74 kg/tree). Midseason flowering 'Harnas' [4 May (daily maximum temperature 11.2 °C)] and 'Frost' [5 May (daily maximum temperature 10.8 °C)] retained the next most fruit (1.33 and 2.18 kg/tree, respectively) at harvest (Table 2). European honeybee is the main pollen vector in Norway and its activity is affected by both rainfall and temperature (Hansted et al., 2012; Puškadija et al., 2009). An earlier study

found that european honeybee activity stops at temperatures lower than 9 °C (Burrill and Dietz, 1981). Typically european honeybee flight activity is normal at temperatures above 12 °C, concurrent with adequate radiant energy (Danka et al., 2006). It is possible that either temperatures of <10.8 °C or reduced radiation as a response to daytime rainfall or a combination of both are most likely the reasons for poor fruit set in 'Champion' and 'Reliance' in 2009, but bud death due to low winter temperatures may also have played a role in this and future research should investigate this aspect.

In 2010, peak flowering began on 17 May and continued for 6 d until 23 May. (Table 1) During this period, daily maximum temperatures ranged between 11.1 °C ('Riga') and 21.4 °C ('Frost', 'Benedicte', and 'Redhaven'). Interestingly, maximum fruit retention was again recorded for 'Harnas' (daily maximum temperature 17.9 °C at peak flowering) and 'Riga' (daily maximum temperature 11.1 °C at peak flowering), namely 6.93 and 2.06 kg/tree, respectively (Table 2). With the exception of 'Riga' daily maximum temperatures at peak flowering for all other cultivars was ≥ 15.7 °C (Table 1). Despite this, fruit set and fruit yield were poor for most other cultivars. This suggests that a daily maximum temperature of ≥ 12 °C is not a guarantee for peach fruit set.

In 2011, peak flowering began on 6 May ('Riga') and continued for 11 d until 17 May ('Reliance') (Table 1). During this period, daily maximum temperatures ranged between 9.3 °C ('Charles Ingouf' and 'Champion') and 17 °C ('Harnas' and 'Vaes Oogst'). Despite most other cultivars experiencing daily maximum temperatures of ≥ 12 °C during peak flowering, only 'Riga' (daily maximum temperature during flowering of 10.4 °C) produced yields greater than 4 kg/tree (Table 4). Clearly, other factors apart from maximum temperature during peak flowering and rainfall play a role in peach pollination and fruit set and further research is implicated.

In 2009, 2010, and 2011, differences in average flowering intensity and average fruit set (Table 3) were highly significant between the different cultivars ($P < 0.001$). In all three years, flowering intensity of early flowering 'Riga' (7.88, 7.00, and 7.25, respectively) and late-flowering 'Reliance' (7.99, 6.00, and 5.00, respectively) were consistently high. Most other cultivars had lower flowering intensities and 'Red Haven' consistently performed poorly (3.38, 4.38, and 1.78, respectively). Average fruit set of 'Riga' was consistently high (7.25, 8.06, and 5.08, respectively), whereas 'Reliance' did not set a large crop each year (3.95, 2.43, and 2.67, respectively). As expected, lower flowering intensities for all other cultivars resulted in relatively poor fruit set. Regression analysis found that when fruit set was fit as a response to flowering intensity using simple linear regression ($P < 0.001$) that a strong positive correlation ($r^2 = 0.939$) exists with the equation: Fruit set = $0.665 \times$ flowering intensity - 0.261.

Clearly, fruit set is strongly influenced by flowering intensity, but fruit set did not necessarily translate into yields at harvest, which implies that fruit drop is a factor, which determines yield (Table 4). Significant differences ($P < 0.001$) between average yield and average yield efficiency (yield/TCSA) for all the cultivars were identical in 2009 through 2011, which implies that rootstock effects on scion growth and yield were negligible. Consequently, yield efficiency data are not presented. Average annual yields in 2009, 2010, and 2011 (Table 4) were consistently

high for 'Riga' (5.74, 2.06, and 4.71 kg/tree, respectively), followed by 'Harnas' (1.33, 6.93, and 0 kg/tree, respectively). Interestingly, 'Harnas' did not have high flowering intensity but did retain most of the fruit that set through to harvest. All other cultivars yielded poorly and we believe this is due in part to the extremely high incidence of peach leaf curl.

Where postharvest quality was concerned, 'Amsden', 'Riga', 'Charles Ingouf', 'Frost', 'Revita', 'Champion', 'Vaes Oogst', and 'Peregrine' averaged greater than 11% soluble solids (results not shown) at harvest, the minimum concentration required for good fruit quality (Kader, 1999). Despite this, 'Riga' fruit were insipid, and we hypothesize that this was most likely due to low acid concentrations and future investigations should examine this aspect. Unfortunately, physiologically induced stone-splitting (results not shown) resulted in cracking of the fruit either at the distal or proximal ends. This was observed most in 'Riga', 'Charles Ingouf', and 'Champion' and least for 'Reliance', 'Harnas', and 'Amsden'. No fruits of 'Amsden June' cracked in 2009, but all fruits cracked in 2010. Stone-splitting made the fruit extremely susceptible to postharvest rots. 'Riga' fruit pedicels were also relatively short, making harvesting difficult. Fruit was extremely susceptible to bruising and subsequent flesh discoloration but when handled carefully, it was possible to store these fruit at 4 °C for 2 weeks in regular atmosphere storage. 'Harnas' fruit were large and spherical, but the pedicels were short, making harvesting difficult. Fruit skins were an even red color and the flavor was excellent, making this the premier choice for Norway. However, one disadvantage of this cultivar was that fruit ripening within individual fruit was uneven. Fruit started to soften from the styler point, while the rest of the fruit, especially toward the stone, remain firm and unripe.

Conclusions

Cultivation of early maturing peach cultivars under cool, mesic conditions in Ullensvang, considered to be one of the most suitable fruit-growing areas in Norway, found that no one cultivar tested was suitable for commercial fruit production. Most cultivars were extremely susceptible

to peach leaf curl, but some cultivars exhibited some tolerance to the disease. Yields of none of the cultivars evaluated approached anything near commercial international standards, e.g., in California, growers would expect to harvest an average of 20 kg/tree in year 4 (Day et al., 2009). The most consistent yielding cultivar in this study was 'Riga' with 5.74 kg/tree in 2009, 2.06 kg/tree in 2010, and 4.71 kg/tree in 2011. 'Harnas' yielded 6.93 kg/tree in 2010, but had very low yields in 2009 and no yield at all in 2011. 'Harnas' was susceptible to peach leaf curl, but both external and internal fruit quality were excellent and those fruit withstood picking and handling and stored well. Consequently, none of the existing cultivars are recommended for commercial plantings in Ullensvang, Norway, in the open. However, looking forward commercial tunnel production and home gardens could consider both 'Harnas' and 'Riga'. Furthermore, we conclude that both 'Harnas' and 'Riga' might make suitable breeding parents, that might give rise to accessions that have some level of tolerance to peach leaf curl, and could result in early maturing fruit with somewhat adequate yields of acceptable fruit quality and good postharvest storability.

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