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Evaluation of New Promising Norwegian Pear Cultivars in a Nordic Climate

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Abstract

Norwegian pear (*Pyrus communis* L.) production has been in decline for the last 25 years. This was mainly because of old cultivars, with low yields and poor consumer appeal, could not compete against strong competition from imported pears, mainly 'Conference'. Since 1994, the Norwegian breeding company, Graminor Ltd., has released several new pear cultivars, which have been evaluated at NIBIO Ullensvang, western Norway. The first trial was planted in 1999 and included the Graminor Ltd. cultivars: 'Ingeborg', 'Fritjof' and 'Anna', which were bred by the Norwegian University of Life Sciences. In 2002, a second trial was planted including Graminor Ltd. cultivars: 'Kristina', 'Ingrid' and 'Celina' and these were compared against a control, 'Clara Frijs'. All scion cultivars were grafted on the semi-vigorous rootstock 'Brokmal' and grown for 8 years. In both trials, full bloom (~80% of flowers open) took place between 7 May $\pm$ 3 days and 15 May $\pm$ 4 days. Flowering was however, completed within a 7-day period in any one year, ensuring adequate overlap in flowering time between all cultivars. Over the final 4-year period all cultivars were evaluated, 'Anna', 'Fritjof", 'Kristina' and 'Ingeborg' all had moderate cumulative yields (64.7, 66.2, 36.1· and 30.4 kg·tree^{-1}, respectively). Fruit weight (212 to 183g) and quality of all these cultivars was acceptable (11.2% $\leq$ TSS $\leq$ 11.8%; 0.16% $\leq$ acidity $\leq$ 0.22%). However, 'Fritjof' had many misshapen fruit and exhibited pre-harvest shriveling in several instances making it unacceptable for commercial plantings. 'Clara Frijs' and 'Celina' cumulative yields were low (12.5 and 21.2 kg per tree, respectively) and fruit were also small (172 to 161 g, respectively). However, due to the attractive cerise-blush 'Celina' (trademarked QTee®) pear is now widely planted in Norway and abroad and grafted on Quince rootstocks.

European pears are temperate fruit, which have an epicenter in China and Asia Minor, but wild types have spread throughout the Middle East (Silva *et al*., 2014). Worldwide, China is the largest producer of pears (1.62 million tons per annum (p.a.)) followed by the United States of America (730,740 tons p.a.) and Italy (716,821tonnes p.a.) (data 2018, FAOSTAT, 2020). Due to the maritime influence of the Hardangerfjord (lat. 60°19'8.03"N, long. 6°39'14.31"E), Ullensvang, western Norway is one of the most northerly tree fruit-producing areas in the world. The waters of the fjord are warmed by the Gulf Stream (Durif et al., 2011) and this together with fertile, arable soils has resulted in continued fruit cultivation for more than 900 years. Mild winters prevail within 300 m of the fjord shoreline and this combined with very long moderately warm days in summer results in a mesic climate that is suitable for the production of many different temperate fruits. Pears (*Pyrus communis* L.) were first planted in Ullensvang in the 1790's (Bleie, 1947) and have been grown here continuously since then. However, over the last 25 years, pear production both here and in other fruit producing areas of Norway has been in

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decline. According to the FAO the current annual production in Norway is less than 2% of the annual amount of pears imported by Norway (FAOSTAT, 2020). This is mainly because of many old cultivars, which do not mature early, produce low yields and have poor consumer appeal. All these factors mean they cannot compete with strong competition from imported pears, mainly 'Conference'.

Since 1994, the Norwegian breeding company Graminor Ltd. has introduced several new pear cultivars including: 'Celina' ('Coloree de Juilett' × 'Williams'), 'Fritjof' ('Clapp's Favorite' × 'Conference'), 'Ingeborg' ('Conference' × 'Bonne Louise'), 'Ingrid' ('Conference' × 'Giffard'), and 'Kristina' ('Clara Frijs' × 'Conference'). Initial screenings started in 1985 (Hjeltnes and Ystaas, 1993) and continued into the early 2000's by Hjeltnes (2011). Grower members of a major Norwegian packinghouse in Ullensvang, began planting 'Ingeborg' pear trees in 1999. The aim was to help prevent declining acreage, raise production of Norwegian grown pears, and increase their own fruit tonnage. Those cultivars represent a new generation of pears. Furthermore, the last five years have seen a significant increase in acreage planted to the blush pear 'Celina' in Norway. We report here on several of these new releases that have been evaluated against two other pear cultivars: 'Anna' ('Clara Frijs' × 'Sierra') by the Norwegian breeder J. Øydvin, Norwegian University of Life Sciences and 'Clara Frijs' (Danish cultivar of uncertain pedigree) at NIBIO Ullensvang, western Norway.

Material and Methods

All scion cultivars were grafted onto the clonal, semi-vigorous 'Brokmal' (OH x F 333) rootstock. The first experiment (Trial 1) was planted in 1999 and included Graminor Ltd. selections 'Ingeborg' (Fig. 1) and 'Fritjof' (Fig. 2) and another selection, 'Anna' (Fig. 3) bred by the Norwegian University of Life Sciences. In the fall of 2002, the second experiment (Trial 2), included 'Ingrid', 'Ce-

Figure 1. 'Ingeborg' ('Conference' × 'Bonne Louise') grown in Ullensvang, western Norway.

Figure 2. Misshapen 'Fritjof' pear ('Clapp's Favorite' × 'Conference') fruit exhibiting dimpling and knobling grown in Ullensvang, western Norway.

Figure 3. 'Anna' pear fruit ('Clara Frijs' × 'Sierra') grown in Ullensvang, western Norway.

Figure 4. 'Celina' (QTee®) ('Coloree de Juillet' × 'Williams') grown in Ullensvang, western Norway.

Figure 5. 'Kristina' ('Clara Frijs' × 'Conference') grown in Ullensvang, western Norway.

lina' (Fig. 4) and 'Kristina' (Fig. 5) and compared them against a check, namely 'Clara Frijs'. Plant materials were one-year-old whips, spaced 2.0 × 4.5 m apart and trained to a central leader as a free spindle. Subsequent pruning and training were performed each winter. Each year in early April, trees were fertilized as a broadcast according to the industry standards established by Ystaas (1971) and Ystaas and Steenberg (1978).

In spring and summer, when necessary, trees were sprayed according to integrated pest management principals with labeled pesticides when local thresholds for pests and diseases were met. In general, tree health was good and insect pressure was low throughout the duration of the trials. Under-canopy management included grass in the inter-rows and clean-cultivated herbicide strips, 1-m wide in the intra-rows. The experimental site had a sandy loam soil with high organic matter (>4%) and with good fertility. Trees were irrigated by drip irrigation when water was deficient, based on evapotranspiration measurements. Trees received the same amounts of fertilizer, based on soil and leaf analysis. Trunk cross sectional area (TCSA), 25 cm above the graft union, was recorded each fall. Phenology of flowering was recorded annually by assessing the dates of start of bloom (first open flowers), full bloom (80% open flowers) and end of bloom (all flowers petals dropped) using the BBCH coding system (Meier et al., 2009). Flower density and fruit set were indexed on a scale of 1 (no flowers or fruit set) to 9 (very dense flowering or fruit set). Experimental design was a randomized complete block design with four replications and two trees per plot. Total yield was measured for each tree yearly. Yield efficiency was calculated as cumulative yield divided by trunk cross sectional area ($kg \cdot cm^{-2}$) for the final harvest year. Individual fruit weights were determined for a random sample of 50 fruit per plot.

A sample of 10 randomly selected fruits from each plot was transported to the lab and used to measure external and internal fruit quality (firmness, soluble solids and acidity). Flesh firmness (N) was measured by a digital table penetrometer with a 5 mm probe (Penefel®, CTIFL France) and soluble solids (%) was measured using a handheld Atago® refractometer (using juice collected from the measurements of flesh firmness). Fruit juice was titrated and percentage malic acid was calculated. Tree vigor, yield, fruit size and fruit quality were evaluated annually for

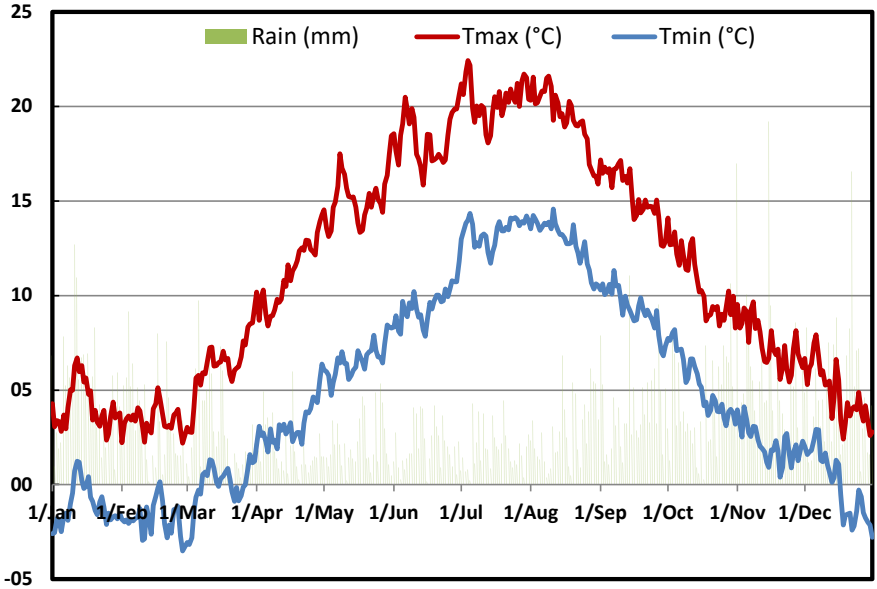

Figure 6. Average daily rain fall, maximum (Tmax) and minimum (Tmin) temperatures in Ullensvang, Norway between the years 2000 and 2010.

eight subsequent years except 2009 when harvest data were not recorded due to reorganization of the research institute.

Daily maximum (Tmax) and minimum (Tmin) temperatures and rainfall during the trial period were recorded by the Ullensvang weather station (Fig. 6).

Data were evaluated by general analysis of variance (ANOVA) for randomized complete block design using the statistical program Minitab® 16 statistical software (Minitab Ltd, UK), testing for differences between all crop load parameters, effects on fruit quality and correlation between daily average temperature at Ullensvang and number of days for fruit development from full bloom until harvest . Unless noted otherwise, only results significantly different at $P \leq 0.05$ are discussed.

Results and Discussion

In both trials, peak flowering (~80% of flowers open) occurred between 7 May ± 3 days and 15 May ± 4 days (Tables 1 and 2). The main flowering period for all cultivars was completed within a 7-day period in any

Table 1. Trial 1 phenology dates of three pear cultivars grown in Ullensvang, western Norway from 1999 to 2008.

Cultivar	Start flowering BBCH 60	Full bloom BBHC 65	End of flowering BBCH 69	Harvest date BBCH 87	Flowering index[z]	Fruit set index[z]
Anna	7 May (±5)	11 May (±5)	23 May (±5)	25 Sept (±6)	6.1 ± 1.7	4.4 ± 1.3
Fritjof	11 May (±4)	15 May (±5)	28 May (±5)	4 Oct (±7)	5.6 ± 1.3	4.3 ± 1.6
Ingeborg	7 May (±5)	11 May (±4)	24 May (±5)	20 Sept (±8)	6.4 ± 1.5	3.3 ± 1.6

[1] assessed on scale of 1 (no flowers) to 9 (very strong flowering); [2] assessed on scale of 1 (no fruit set) to 9 (very high fruit set) (± standard deviation).

Table 2. Trial 2 phenology dates of four pear cultivars grown in Ullensvang, western Norway from 1999 to 2008.

Cultivar	Start flowering BBCH 60	Full bloom BBHC 65	End of flowering BBCH 69	Harvest date BBCH 87	Flowering[z] index	Fruit set[z] index
Celina	8 May (±6)	13 May (±7)	22 May (±7)	20 Sept (±13)	3.6 ± 1.5	3.0 ± 1.0
Clara Frijs	6 May (±7)	10 May (±7)	19 May (±8)	23 Sept (±13)	2.3 ± 0.9	2.0 ± 0.6
Ingrid	7 May (±5)	11 May (±6)	21 May (±6)	26 Aug (±4)	4.1 ± 1.6	4.4 ± 0.7
Kristina	8 May (±5)	14 May (±6)	22 May (±7)	24 Sept (±10)	2.9 ± 1.1	3.6 ± 1.0

[z] assessed on scale of 1 (no flowers) to 9 (very strong flowering); [z] assessed on scale of 1 (no fruit set) to 9 (very high fruit set) (± standard deviation).

one year with an adequate overlap to ensure pollination between cultivars. Julian days are a better estimate to predict pear flowering than heat units. Modelling of heat units using different base temperatures of 1, 2, 3, 4 and 5°C to predict flowering did not result in any improvement in predictions (results not shown). The cultivars 'Ingrid' had the earliest maturing fruit (26 Aug.) (Table 2) and 'Fritjof' (Table 2) had the latest maturing fruit (4 Oct.). All other cultivars were harvested between 20-26 Sept. The number of days for fruit development from bloom until harvest showed an inverse linear relationship with the average day temperature. Figure 7 shows that for 'Ingeborg' this development period decreased by ca. 8.5 days per centigrade temperature rise from ca. 142 days at 13° C to 125 days at 15°C. Meland et al. (2020) observed this same relationship for 'Ingeborg' grown on a 'Quince C' rootstock in a more recent trial in Ullensvang. Cumulative yields of 'Fritjof' (66.2 kg/tree) and 'Anna' (64.7 kg/tree) were twice that of 'Ingeborg' (30.4 kg/tree) while both 'Ingrid' (25.2 kg/tree) and 'Celina' (21.2 kg/tree) had much lower yields (Table 4) but all were higher than the control 'Clara Frijs', which had very low cumulative yields (13.5 kg/tree). In addition, yield efficiencies confirmed these findings as 'Clara Frijs' had a much lower yield efficiency (0.4 kg·cm^{-2}) compared to all other cultivars (≥0.7 kg·cm^{-2}). As expected, both 'Anna' and 'Fritjof' had the highest yield efficiencies (2.6 and 2.3 kg·cm^{-2}, respectively) (Table 3).

The rootstock 'Brokmal' has rather higher vigor and the trees came slowly into pro-

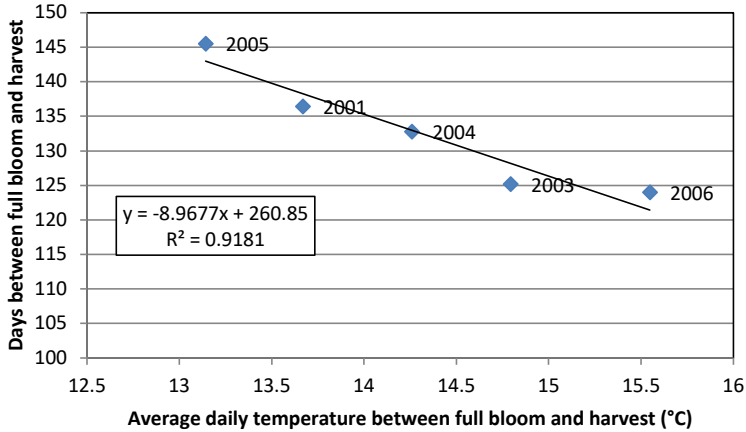

Figure 7. Relationship between daily average temperature at Ullensvang and number of days for fruit development from full bloom until harvest in 'Ingeborg pear' in years 2000 to 2006.

Table 3. Trial 1 fruit production and fruit quality data of three pear cultivars grown in Ullensvang, Western Norway from 1999 to 2008.

Cultivar	Cum.yield (kg/tree)	Fruit weight (g)	TCSA (cm^2)	Yield efficiency (kg/cm^2)	Firmness[z] (N)	Soluble solids (%)	Acids (%)
Anna	64.7 a	183 b	25.2 b	2.6 a	65.7	11.8	0.22 a
Fritjof	66.2 a	209 a	29.1 b	2.3 a	67.7	11.7	0.16 b
Ingeborg	30.4 b	212 a	37.3 a	0.8 b	70.6	11.6	0.22 a
F-test	P<0.001	P<0.05	P<0.001	P<0.001	NS	NS	P<0.001

[z] measured with a 5 mm diameter plunger

Table 4. Trial 2 fruit production and fruit quality data of four pear cultivars grown in Ullensvang, Western Norway from 1999 to 2008.

Cultivar	Cum. yield (kg/tree)	Fruit weight (g)	TCSA (cm^2)	Yield efficiency (kg/cm^2)	Firmness[z] (N)	Soluble solids (%)	Acids (%)
Celina	21.2 b	172 a	37.4	0.7 ab	44.1 abc	11.8 ab	0.12 c
Clara Frijs	13.5 b	161 ab	34.9	0.4 b	40.2 bc	11.8 ab	0.21 a
Ingrid	25.2 ab	139 b	31.0	0.9 ab	36.3 c	12.6 a	0.15 bc
Kristina	38.5 a	185 a	36.1	1.1 a	46.1 ab	11.2 b	0.19 ab
F-test	P<0.001	P<0.001	NS	P<0.05)	P<0.001	P<0.001	P<0.05

[z] measured with a 5 mm diameter plunger

duction, but when tested on the dwarfing Quince rootstocks 'Adams', 'C' and 'Eline®' the pear cultivars 'Celina', 'Ingeborg' and 'Kristina' gave much higher yields (Meland et al. 2020). Furthermore, it should be noted that despite cumulative yields of 'Anna' and 'Kristina' being acceptable by Norwegian standards they are still low compared to other European countries. The average yield of mature 'Celina'/'Quince C' trees grown at the fruit research station in Sint Truiden in Belgium ranged between 50 and 60 tons per hectare (Vercammen, 2019).

Under the cool mesic conditions of western Norway however, we believe the lack of a suitable pollinizer to be the cause of low yields and small fruit size. For that reason, pollinizer efficacy of several pollinizers for 'Ingeborg' were investigated recently in the Hardanger district by using 12 microsatellite markers and 'Clara Frijs' and 'Belle lucrative' were identified as the most efficient pollinizers (Gasi et al., 2017). Besides, success rate of different pollinizer by controlled crossing of 'Ingeborg and 'Celina' has been tested under field conditions in Norway. Based on flowering overlap, success rate of each individual pollinizer, fruit set, and pollen tube growth followed under fluorescent microscopy, the cultivars 'Anna' and 'Clara Frijs' could be suggested as the most suitable pollenizers for 'Ingeborg', and 'Fritjof', 'Anna' 'Kristina' and 'Herzogin Elsa' for 'Celina' (Cerovic et al., 2020). However, even in orchards with sufficient and suitable pollenizer trees, the weather conditions during bloom in Norway often are unfavourable for pollination by insect pollinators.

Fruits from 'Ingrid' were significantly smaller than all other cultivars (139 g) (Table 4), but they were significantly sweeter (12.6% soluble solids) than all other cultivars (≤11.8%). Nonetheless, because of the markedly small fruit size, we do not consider 'Ingrid' acceptable for commercial production in Ullensvang. 'Ingeborg' and 'Fritjof' (Table 3) produced significantly larger fruit (212 and 209 g) than all other cultivars (≤185g)

but unfortunately, many 'Fritjof' fruit shriveled on the tree and exhibited both dimpling and bumps (Fig. 2) making them unsightly and unlikely to be acceptable to consumers.

Generally all tested cultivars were sweet and had very low acid. 'Kristina' had the lowest total soluble solids (11.2%) (Table 4). 'Anna' and 'Clara Frijs' had significantly higher acidity (≥0.21%) than all other cultivars (≤0.19%) but 'Celina' had significantly lower acid than all other cultivars (0.12%) (Table 4). This is at the same levels Vangdal (1986) found for Norwegian pears.

The soluble solids and titratable acids ratio varied between the cultivars from 98 (in 'Celina') to 53 (in 'Anna' and 'Ingeborg'). 'Celina' does however, have an attractive cerise-blush fruit, which gives it considerable consumer appeal. Some 'Fritjof' fruit exposed to full sunlight also had an attractive red-blush.

The cultivar 'Celina', is commercialized as a club variety (trademarked QTee®). The production volume is still minor compared to the most popular cultivars in Europe like 'Conference', 'Doyenne du Comice' and 'Abate Fetel'. However, 'Celina' obtains a good fruit price for the growers and the orchard area is controlled to keep the fruit production volume balanced with the market demand.

Main pests in Norwegian pear orchards are pear scab (*Venturia pyrina*), European pear sucker (*Cacopsylla pyrina*) and capsid infestations (*Fam. Miridae, Pentatomidae and Acanthosomatidae*) (Hesjedal and Vangdal 1986). All the cultivars were susceptible to pear scab except for 'Kristina'. 'Ingeborg' pears had more damage by capids causing stone pits than the other cultivars (data not shown). Pear suckers were not a problem these years.

Conclusions

'Anna' from the Norwegian University of Life Sciences, and Graminor Ltd. selections 'Fritjof', 'Kristina' and 'Ingeborg' all yielded at an acceptable level for Norwegian conditions, when compared to all other local cultivars and all except 'Fritjof' (based on pre-harvest shriveling and misshapen fruit) are recommended for commercial plantings. Interestingly, 'Clara Frijs', the Danish cultivar, yielded very poorly under these growing conditions, rendering it less desirable for commercial production in western Norway. Furthermore, 'Celina', an attractive cerise-blush pear, has been trademarked as QTee®, and is widely planted in other European countries. Due to the highly attractive skin color, 'Celina' remains a cultivar of interest. By choosing a dwarfing rootstock and selecting the right pollinizers, yields of these cultivars will be substantially improved.

Acknowledgements

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Correction:

In Volume 75, number 2, page 112, Fig. 3, the caption should read

Fig. 3. Prosper Berckmans seated and sons (l to r) Prosper Jr. (Allie), Robert, and Louis. Photo courtesy Augusta National/Masters Historic Imagery via Getty Images.