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White nectarines bloom, harvest degree days, yield and fruit traits over a span of five years in the intermountain region of the United States

Esmaeil Fallahi*, Bahar Fallahi, Michael J. Kiester and Thomas M. Elias

*Pomology and Viticulture Program, University of Idaho, Parma Research and Extension Center, 29603 U of I Lane, Parma, ID 83660, USA. *E-mail: efallahi@uidaho.edu*

Abstract

White-fleshed nectarines have gained popularity in recent years but there is limited information on their adaptability. Thus, the objective of this trial was to investigate growing degree-days (GDD; base temperature of 4.4 °C), full bloom and harvest dates, fruit quality, and yield of five white-fleshed nectarines [(*Prunus persica* var. *nectarine)*] under conditions of southwest Idaho in the Intermountain Region of the United States during 2003-07. The average response analyses over these years indicated that 'Arctic Jay' and 'Arctic Pride' bloomed earlier, while 'Arctic Mist' bloomed later than other cultivars. Arctic Jay was the earliest and Arctic Snow was the latest cultivar to harvest and needed 136 days and 181 days between full bloom and harvest, respectively. On average, 'Arctic Pride', 'Arctic Mist', and 'Arctic Snow' were harvested after the second half of September, and the periods between bloom and harvest for these cultivars were 166, 180, and 181 days, respectively. The difference between the earliest and latest cultivar for full bloom dates was only 2 days or 14 °C GDD, while the range for harvest dates was 16 days or 608.2 °C GDD. 'Arctic Jay' had excellent fruit quality attributers and on average, was harvested on 21 August. 'Arctic Pride' had moderately large fruit size and high SSC and extremely attractive skin and flesh color, but had moderately low yield. Considering all factors evaluated in this project, 'Arctic Jay', 'Arctic Queen', and 'Arctic Pride' were suitable choices for early, mid, and late season cultivars, respectively. 'Arctic Mist' could have some potential for planting in this study. The growing season was not sufficient to mature 'Arctic Snow' and thus not recommended for the region.

Key Words: cultivar performance, fruit flavor, nectarine selection, stone fruit adaptability

Introduction

According to the Idaho Fruit Tree Census (United States Department of Agriculture, 2007), peaches constituted 21% and nectarines constituted 2% of the total tree fruit production in Idaho in 2006, which is a considerable increase as compared to 1999. The increasing production of nectarines and peaches in the Intermountain West region is due to the national and international market demand for the high quality stone fruit that can be produced under the high desert conditions of southwest Idaho and central Washington. Warm dry days and cool nights during the growing season and at fruit maturity create suitable conditions for growing high quality nectarines and peaches in these regions.

Similar to the situation in other nectarine- and peach-producing states (Frecon *et al.,* 2002), many suitable orchard sites are taken for development and urbanization in Idaho. New nectarine and peach orchards are often planted in old 'Delicious' apple orchard sites. The pressure for urbanization and the competitive nature of world markets mandate production of new cultivars with high quality that mature in a span of time for a wide market window. In reports by Huang *et al.* (2008) and the California Tree Fruit Agreement (CTFA, 2003), peaches and nectarines are classified into five categories according to the length of the period between full bloom and harvest: 1) very early cultivars- less than 65 days from full bloom to harvest, 2) early cultivars- 66-90 days from full bloom to harvest, 3) mid-season cultivars-91-120 days from full bloom to harvest, 4) late-season cultivars-121-150 days from full bloom to harvest, and 5) very late cultivars- which have more than 151 days from full bloom to maturity. Based on California Tree Fruit Agreement (2003), of the total production of 186,660 metric tons of leading nectarines in California during 2002-03, 14.2, 35.3, 25.0, 19.2, and 6.3% were produced in May, June, July, August, and September, respectively. Cultivars in each group have their advantages and disadvantages, and they are planted according to the marketing outlet and strategy of each grower.

In spite of the increasing commercial importance of white-fleshed nectarine production, there is no comprehensive and comparative information on the bloom and harvest dates, yield, or quality of this fruit. The goal of this long-term project was to investigate the growing degree-days, bloom and harvest dates, yield, and fruit quality of various white-fleshed nectarines under conditions of southwest Idaho in the Intermountain region of the United States, in order to identify the most promising cultivars for commercial use and export market.

Materials and methods

Orchard description and cultural practices: The orchard for this study was established at the University of Idaho Parma Research and Extension Center, near Parma in southwestern Idaho, which is a representative area of fruit-producing orchards in the Intermountain Western region in the United States with annual precipitation of about 274 mm, latitude 43°48' 00"N, longitude 116°56'00", an average minimum daily temperature of -27.6 °C

in January and an average maximum daily temperature of 34.3 °C in July, and elevation of 702.6 m.

Uniform certified nectarine trees on 'Nemaguard' rootstock with 1.27 cm trunk diameter (at planting) were obtained from Dave Wilson nursery in California. Five white-fleshed nectarine cultivars (Arctic Jay, Arctic Queen, Arctic Pride, Arctic Mist, Arctic Snow) were planted at 2.4 x 5.0 m in April 2000.

Trees were trained into a 4-leader vase shape. The soil was sandy loam with a pH of 7.1 to 7.3. Urea nitrogen ($CO(NH_2)_2$ mixed with potassium chloride (KCl) and P were applied during the month of May annually to provide actual amounts of N, P, and K at rates of 123.2, 61.6, and 67.2 $kg.ha^{-1}$ per year, respectively. This mixed fertilizer was broadcasted in an approximately 1-m band on either side of tree rows.

Trees were irrigated weekly with sprinkler system to match the evapotranspiration requirements for nectarine (ETc). We used information from the Agrimet Weather Station at the University of Idaho, Parma, Idaho, to calculate *etc*. Annual pruning, spraying and other cultural practices were similar to those of commercial orchard in the region (Washington State University, 2014). Fruits were thinned by hand just before pit hardening stage (about 6 weeks after full bloom) to maintain a 12 to 15 cm spacing between fruits.

Bloom and harvest dates, growing degree days, yield, and quality: Dates of full bloom (about 80% blooms open) and commercial harvest (when most of the fruits were ready to be harvested as judged visually by flesh and skin color) were recorded every year in 2003-07 for each tree. In addition to the actual dates, 'day of the year' (DY) for full bloom and harvest dates was also recorded. Daily growing degree-days (DGDD) from 1 Jan. to full bloom and harvest dates were calculated as: [(daily maximum plus minimum temperatures in Centigrade/2) –(4.4 °C)]. Cumulative growing degree-days (GDD) were calculated as the sum DGDD to the full bloom or harvest dates for each cultivar in each year. We chose to use 4.4 °C as the base temperature in the DGDD calculations because even at these low temperatures bloom will still develop although the rate of development is slower (E. Fallahi, personal observation, unpublished data).

Fruit color and total yield per tree were recorded at harvest time every year between 2003 and 2006. Ten fruits were randomly sampled from each tree in the middle of commercial harvest time. Average fruit weight during 2003 to 2005 and soluble solids concentration (SSC) in 2004 and 2005 were measured with a hand-held temperature-compensated refractometer (Atago N1, Tokyo, Japan). Fruit skin and flesh color were inspected visually and described.

Experimental design: The experiment was arranged as a complete randomized design with six one-tree replications per cultivar. Data were analyzed using general linear model (GLM) procedures. Fisher's protected LSD ($P \leq 0.05$) was used to separate treatment means. Statistical analyses were carried out using SAS (version 9.2; SAS Institute, Cary, NC).

Results and discussion

General observations: Although we did not measure trunk cross sectional area or yield efficiency, total yield per tree could be used as an acceptable tool (but not exact) of yield efficiency, because trees were maintained at about 3.8 m height in all the cultivars. Tree survival and insect and disease susceptibility among all tested cultivars were similar in this experiment (data not shown).

Bloom dates and growing degree-days for bloom: Nectarine cultivars are listed according to ascending order of long-term average full bloom dates and DY for full bloom (Table 1). Considering all cultivars over the period of 2003 to 2007, dates of full bloom ranged from 7th to 9th of April (total of 2 days), which equated to 13.9 GDD. On average, 'Arctic Jay' and 'Arctic Pride' bloomed earlier (7 April), while 'Arctic Mist' bloomed later than other cultivars (9 April). In this experiment, the variation for full bloom time was greater between years than among cultivars within a given year. Trees within each cultivar and each year had very small variation in their full-bloom dates due to the tree and soil uniformity (data not shown). There was no significant interaction between years and cultivars for any of the bloom date measurements. This knowledge will facilitate cultural practices such as blossom thinning that would be difficult otherwise (if wide tree-to-tree or year-to-year variation occurred).

During warmer seasons, differences still existed between cultivars but the differences were less than those in cooler seasons. For example, GDD for the period between 30 March and 25 April was 204 in 2004 and 144 in 2005 (data not shown). However, the difference between the earliest-and the latest blooming cultivar was 2 days in 2004 and 3 days in 2005 (Table 1). Historically, cultivars with later blooming dates have less chance of spring frost. Therefore, the very late-blooming cultivars such as 'Arctic Mist' may have a slightly lower chance of frost damage.

Commercial harvest date and growing degree days for harvest: Cultivars in Tables 2-4 are arranged in ascending order of their 2003-07 average harvest dates and DY for these dates. Significant differences ($P \leq 0.05$) existed in commercial harvest dates and GDD to harvest among cultivars (Table 2). Harvest date for each cultivar varied from year to year, but the order of harvest among cultivars the generally same in each season and no significant interaction existed between cultivars and years. The range among cultivars was more spread for their harvest dates compared to bloom dates. For example, averaging values over 2003-07 revealed that the difference between the earliest and latest cultivar for full bloom dates was only 2 days or 13.9 °C GDD, while for harvest dates it was 45 days or 608 GDD °C (difference between 21 August and 6 October). The earliest cultivar in our evaluation was 'Arctic Jay' with136 days between full bloom and harvest, and on average, was harvested on 21 August. Thus, the earliest cultivar in our evaluation fits in the late-season category of Huang *et al.* (2008). 'Arctic Pride', 'Arctic Mist' and 'Arctic Snow' were harvested after the second half of September, and the periods between bloom and harvest for these cultivars were 166, 180, and 181 days, respectively. Thus, these nectarines are considered as "very late" cultivars according to the California Tree Fruit Agreement (2003) and Huang *et al.* (2008) categorization.

Table 1. Full bloom date (FB), growing degree-day (GDD) and average day of the year to full bloom in white-fleshed nectarines grown under southwest Idaho conditions (listed in ascending order of their FB dates [zy])

Cultivar	Type of flower	Full bloom (FB) dates						Mean GDD[x] (2003-07)	Mean day of the year for FB (2003-07)
		2003	2004	2005	2006	2007	Mean 2003-07		
Arctic Jay	Showy	1 Apr.	3 Apr.	9 Apr.	17 Apr.	3 Apr.	7 Apr.	209.4	97
Arctic Pride	Showy	1 Apr.	3 Apr.	7 Apr.	19 Apr.	3 Apr.	7 Apr.	209.4	97
Arctic Snow	Showy	2 Apr.	5 Apr.	10 Apr.	19 Apr.	5 Apr.	8 Apr.	217.2	98
Arctic Queen	Showy	2 Apr.	5 Apr.	10 Apr.	19 Apr.	6 Apr.	8 Apr.	217.2	98
Arctic Mist	Showy	3 Apr.	5 Apr.	10 Apr.	20 Apr.	5 Apr.	9 Apr.	223.3	99
LSD ($P \leq 0.05$)								5.2	

[z] abbreviations: Apr.=April. [y] Mean separation within columns using LSD at 5% significant level. [x] GDD=cumulative Growing Degree-days from 1 Jan., °C= ∑[(daily maximum plus minimum temperatures in Centigrade/2) –(4.4 °C)].

In the highly competitive nectarine market, in addition to the climatic conditions, time of harvest (early, mid or late season), quality attributes, and yield should be considered before planting a cultivar. According to the California Tree Fruit Agreement (2003), of the total nectarines produced in California during 2002-2003, 14.2, 35.3, 25.1, 19.2 and 6.2% were harvested in May, June, July, August, and September, respectively. A comparison of results of selected cultivars used in both the California Tree Fruit Report (2003) and our experiment revealed that nectarines were harvested several weeks later in southwest Idaho than in California. It is noteworthy that the harvest date differences between California and Idaho were greater for earlier maturing than later maturing cultivars (Table 2). For example, these differences between the two states were 42 days for 'Arctic Pride', while it was 30 to 34 days for the late-ripening cultivars of 'Arctic Mist' and 'Arctic Snow', respectively. In New Jersey, 'Arctic Jay', 'Arctic Queen', 'Arctic Pride', and 'Arctic Snow' were harvested on 6 August, 24 August, 2 September, and 8 September, respectively (Frecon *et al.,* 2002). However, in southwest Idaho, these three cultivars were harvested between 15 and 28 days later (Table 2). Comparison of these harvest days underscores the importance of knowing harvest dates of various nectarines in southwest Idaho. Our early-season nectarines were harvested at the time when many mid-season nectarines from California are in the market. Thus, our early cultivars would be suitable for local and farmers' markets. However, middle- and late-season nectarines (Table 2) are harvested at the time when the California market for those cultivars has either slowed down or finished, and thus provide an excellent market window for growers in southwest Idaho and other similar regions in the Intermountain Western USA.

Fruit color: All cultivars developed attractive flesh and skin color due to warm days and the cool nights in the area. Fruits in all cultivars studied here had regions of dark red and creamy-white on the skin, while flesh color was uniform creamy with pink-to-red stains around the pit (Table 3).

Fruit yield and weight: Several cultivars had lower yield in 2003 compared to other years because the trees were young (Table 4). There was no strong correlation between yield and time of harvest in these cultivars. 'Arctic Pride' had larger but 'Arctic Queen' had smaller fruit than all other white-fleshed nectarines (Table 4). 'Arctic Pride' had lower yield than other cultivars in 3 of 4 years of our study and this relationship could have contributed to the larger fruit size in 'Arctic Pride'. In New Jersey, however, fruit size of 'Arctic Pride' was similar to those of 'Arctic Snow' and 'Arctic Queen' (Frecon *et al.,* 2002), perhaps due to location-cultivar interactions between New Jersey and Idaho for these cultivars. Nevertheless, 'Arctic Jay' had a higher average fruit weight than 'Arctic Queen' in both our research (Table 4) and New Jersey (Frecon *et al.,* 2002). All trees in this experiment

Table 2. Harvest date (HD), growing degree-days (GDD) and day of the year (DY) for HD in white-fleshed nectarines under conditions of southwest Idaho (listed in ascending order of their average harvest dates[z])

Cultivar	Harvest date (HD)							GDD[x] for harvest	Average DY for harvest	Full bloom to harvest (days)
	2003	2004	2005	2006	2007	Mean HD 2003-07	California HD[y]			
Arctic Jay	17 Aug.	15 Aug.	24 Aug.	26 Aug.	24 Aug.	21 Aug.	-	2235.3	233	136
Arctic Queen	4 Sept.	4 Sept.	16 Sept.	13 Sept.	13 Sept.	10 Sept.	-	2557.6	253	155
Arctic Pride	14 Sept.	16 Sept.	23 Sept.	24 Sept.	22 Sept.	20 Sept.	8 Aug.	2669.4	263	166
Arctic Mist	16 Oct.	27 Sept.	7 Oct.	3 Oct.	5 Oct.	6 Oct.	6 Sept.	2843.5	279	180
Arctic Snow	5 Oct.	1 Oct.	7 Oct.	3 Oct.	16 Oct.	6 Oct.	2 Sept.	2843.5	279	181
LSD ($P \leq 0.05$)								92.8	9	10

[z] Mean separation within columns using LSD at 5% significant level.
[y] Data in this column is taken from California (CTFA, 2003) for comparison.
[x] GDD=cumulative Growing Degree-days from 1 Jan., °C= ∑:[(daily maximum plus minimum temperatures in Centigrade/2) –(4.4 °C)].

Table 3. Fruit skin and flesh color of white-fleshed nectarines grown under southwest Idaho conditions)listed in ascending order of their average harvest dates)

Cultivar	Fruit skin color	Flesh color	Comments
Arctic Jay	Red to very dark maroon with cream stain	White with red in cavity	Excellent flavor
Arctic Queen	Pink to dark maroon with cream stain	White with pink stain near the pit	
Arctic Pride	Red to dark red with white spots	White	Very late white-fleshed
Arctic Mist	Cream with medium to dark maroon spot	White with narrow pink line around the pit	Excellent but late
Arctic Snow	Cream with medium pink to dark maroon blotches	White with narrow pink line around the pit	Excellent but late

Table 4. Fruit weight, yield, number of fruit, and soluble solids concentration for white-fleshed nectarines under conditions of southwest Idaho (listed in ascending order of their average harvest dates)

Cultivars	Fruit weight (g)				Yield (kg/tree)					Avg. fruit No./tree 2003-06	Soluble solids concentration (°Brix)		
	2003	2004	2005	Mean	2003	2004	2005	2006	Mean		2004	2005	Mean
Arctic Jay	134.3	179.3	212.1	175.2	8.89	13.4	14.6	21.1	14.49	83	15.9	16.0	16.0
Arctic Queen	135.2	141.3	159.3	145.3	6.11	12.1	10.8	24.1	13.27	91	18.1	19.0	18.6
Arctic Pride	188.3	181.3	215.9	195.2	2.46	13.6	7.7	19.9	10.91	56	14.0	14.8	14.4
Arctic Mist	159.1	195.8	178.5	177.8	6.47	5.7	14.1	21.1	11.81	66	15.6	15.0	15.3
Arctic Snow	159.3	165.9	172.3	165.8	9.64	10.8	12.8	30.5	15.94	96	16.3	15.9	16.1
LSD ($P \leq 0.05$)	15.2	16.2	16.5	12.2	2.20	4.0	5.0	5.5	4.20	5	1.0	1.3	1.0

[z] Mean separation within columns using LSD at 5% significant level

were pruned and thinned uniformly, and thus the fruit weight differences are true cultivar effects.

Fruit soluble solids concentration (SSC): Fruit in all cultivars had greater than 14.0 °Brix SSC (Table 4). This finding is in general agreement with Frecon *et al.* (2002) who worked with a different set of nectarines, and reported that early-maturing cultivars had lower SSC. 'Arctic Queen' had significantly higher SSC (overall average of 18.6 °Brix) than all other cultivars. Averaging over years, 'Arctic Jay' tended to have higher SSC than 'Arctic Pride' and 'Arctic Mist' (Table 4). Frecon *et al.* (2002) also reported that 'Arctic Jay' was among cultivars with high SSC in New Jersey. It is noteworthy that 'Arctic Jay', 'Arctic Queen' and 'Arctic Snow' were among cultivars with high yield while their average SSC values were greater than 16 °Brix (Table 4).

Overall performance: Considering all factors evaluated in this project, we believe that 'Arctic Jay' is suitable as a late-August cultivar (Table 2). On average, 'Arctic Jay' had a satisfactory level of yield and fruit size and was harvested on 21August. This fruit had a very attractive fruit skin and white-fleshed color with an outstanding flavor and aroma. Consumer preference for this nectarine was extremely high during numerous field days and taste-testing panels that we offered at the University of Idaho.

For the cultivars that matured during the period of 14 to 20 September, 'Arctic Pride' performed relatively well with respect to fruit size (average of 195.2 g), appearance, and SSC, and would be the white-fleshed cultivar of choice for the region in that period. The lower yield of this cultivar (Table 2) can be economically compensated by its larger fruit size, because consumers would pay a higher price for larger nectarines. We therefore recommend planting this cultivar as a very late cultivar (166 days from bloom to harvest) for the region.

'Arctic Mist' had excellent fruit quality, and can be planted only if there is a demand for extremely late cultivars. But, realistically, 'Arctic Mist' and 'Arctic Snow' are often too late for Idaho. On average, these cultivars were harvested on 6 October (180 and 181 days after bloom, respectively). The harvest dates for these two cultivars ranged from 27 September (for 'Arctic Mist' in 2004) to 16 October (for 'Arctic Mist' in 2003 and for 'Arctic Snow' in 2007), and these harvest dates conflict with the harvest period of several important apple cultivars of the region.

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