FINAL PROJECT REPORT
WTFRC Project Number: CH-04412

Project Title: Clonal rootstock evaluations

PI: M. Whiting
Organization: WSU-IAREC
Telephone/email: 786-9260/mdwhiting@wsu.edu
Address: 24016 N. Bunn Road
City: Prosser
State/Province/Zip WA/99350

Cooperators: W.E. Howell, NRSP5/IR2 Manager, WSU-Prosser
D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser

Budget History:

Item	**Year 1:** 2004	**Year 2:** 2005	**Year 3:** 2006
Salaries	6199	6301	6553
Benefits	1736	1953	2031
Wages	6000	8000	8000
Benefits	960	1280	1280
Equipment	1500		
Supplies	2000	2000	2000
Travel	1500	1500	2000
Miscellaneous			
Total	19895	21034	21864

OBJECTIVES:

1. Continue evaluation of the NC-140 regional project trial ('Bing' on 17 new rootstocks) established in 1998 for horticultural and physiological evaluations and fruit quality. Projected trial duration is 10 years.

2. Continue evaluating vigor and cropping performance of other orchard trials with key PNW cultivars on various rootstocks

3. Analyze the physiology of interactive rootstock/scion horticultural traits (e.g., canopy leaf area, yield efficiency, precocity, graft compatibility).

4. Establish planting of 2005 NC-140 sweet cherry rootstock trial.

SIGNIFICANT FINDINGS:

- high quality fruit can be grown on precocious, dwarfing rootstocks
- Gisela 5 and Gisela 6 are recommended for Bing
- rootstock affected scion vigor, yield, and fruit quality
- rootstock altered 'Bing' fruit maturity (ca. 5 days) and bloom timing (4 days) significantly
- fruit yield was unrelated to tree vigor
- fruit maturity was unrelated to tree vigor
- tree vigor was related negatively to bloom date (i.e., smaller trees bloom earlier than large trees)
- the Gisela series is very precocious/productive
- Gisela 6 induced the greatest cumulative yield (1998 - 2006) of fruit 10.5-row and larger (160 kg/tree), Mazzard induced the third least among rootstocks (49.6 kg/tree)
- Mazzard had the lowest yield in 2006 (19.3 kg, 42.5 lb/tree) but the highest quality fruit
- the worst quality fruit was harvested from Gisela 209/1 and Edabriz
- no rootstock out-performs Gisela 5 or Gisela 6 in the vigorous – semi-dwarfing categories
- PiKu 1 is less vigorous and more precocious than PiKu 3
- novel crop load management strategies will need to be developed to grow high quality sweet cherries on precocious and dwarfing rootstocks

METHODS:
The 1998 NC-140 plot was planted at WSU-Prosser's Roza Experimental Unit, with 'Bing' as the scion cultivar and 'Van' as the pollenizer, on the German rootstock series Gisela 4 (GI 473/10), Gisela 5 (GI 148/2), Gisela 6 (GI 148/1), Gisela 7 (GI 148/8), GI 195/20, GI 209/1, and GI 318/17; the German rootstock series Weiroot 10, W13, W53, W72, W154, and W158; Edabriz (France); P-50 (Japan); and Mazzard and Mahaleb seedlings as controls. There are 8 replications/rootstock, with guard tree around the plot perimeter, and tree spacing of 19.5 x 19.5 ft (6.0 x 6.0 m) to reduce the potential influence of neighboring trees. Irrigation by microsprinklers and frost protection by wind machine were installed. A duplicate plot was planted for potentially destructive analyses, such as physiological stress treatments. The effects of rootstock on tree yield, vigor, fruit quality, first and full bloom dates, fruit maturity, and senescence and cold acclimation will be documented annually.

A research orchard was planted in 1998 with WSU-Prosser varieties (including Chelan, Cashmere, Benton, Selah, Rainier and Tieton) and elite selections (including 8011-3, 7147-9, and 7903-2) on several Gisela rootstocks (including Gisela 5, 6, 195/20, and 209/1), Mazzard, Mahaleb, and Colt. In this block, tree vigor, fruit yield and quality, and graft compatibility will be monitored. Several of these newly released cultivars (*e.g.*, Chelan, Tieton, Benton, Selah) and advanced selections (*e.g.*, PC 8011-3, PC 7903-2, PC 7147-9) will be subjected to one of two crop load treatments: (1) unthinned control, and (2) 50% removal of blossoms by hand. Tree growth, fruit yield and quality (weight, row-size distribution, soluble solids, and firmness) will be evaluated for each scion grown on Gisela 6, Gisela 5, Gisela 195/20, and Edabriz, where possible.

Another orchard, planted in 2001, will be utilized to evaluate the effects of two new rootstocks (PiKu 1 and PiKu 3) on growth, precocity, fruit quality, and graft compatibility of Celeste, Benton, Selah, Tieton, Regina, Bing, Skeena, Sweetheart, Attika, Rainier, Lapins, Chelan, Summit, Black Gold, White Gold, Glacier, and Sonata.

In a separate trial in cooperation with Amy Iezzoni of MSU, we have planted 21 MSU rootstock selections, totaling 117 trees, in a test plot at the Roza farm. The control rootstock is GI 6 and the scion is Bing with Tieton/GI6 as the pollinator. An additional 243 trees (84 selections) will be planted in 2004. The effects of rootstock genotype on scion growth habit, precocity, and fruit quality will be documented annually.

RESULTS AND DISCUSSION:

1998 NC-140 trial

Productivity 2006 was the sixth fruiting year (9th leaf) for most of the rootstocks in this trial and we recorded tremendous variability in fruit yield per tree (19 – 82 kg/tree) (Fig. 1, Table 1). Clearly, rootstock has a significant effect on 'Bing' precocity and productivity (Fig. 1). In 2006, 16 of the 17 rootstocks in this trial exhibited greater productivity compared to the industry standard, Mazzard. In this 9th season, many trees have reached full production; most notably so are those in the Gisela series (e.g., Gi 7, Gi 5, Gi 6, Gi 195/20). In 2005, mean yield was 52.0 kg/tree, about 2.5 times greater yields than the previous year. The most productive rootstocks were from the Gisela series (Fig. 1, Table 1). The least productive rootstocks were unchanged from 2005: W53, P-50, and Mazzard. Trees on each of these rootstocks yielded about 20 kg (45 lbs) per tree. For W53, by far the most size-controlling of the rootstocks, low yields were due to limited canopy size and therefore inadequate bearing surface. We conclude that, even at a high tree density, this rootstock is too dwarfing to produce commercially acceptable yields. However, for P-50 and Mazzard, low yields are inherent and due to poor floral bud induction. The lack of yield from Mazzard-rooted trees remains a significant concern and its greatest drawback.

Cumulative yield data (2001 – 2006) reveal the overall lack of productivity on Mazzard (Fig. 2). Mazzard-rooted trees yielded only 5.7 tons of 10.5-row and larger fruit per acre between 2001 and 2006 (i.e., less than 2 tons per year). Mazzard was the third-least productive rootstock of 10.5-row+ fruit among all 17. The rootstock yielding the greatest quantity of 10.5-row+ fruit was Gisela 6. Between 2001 and 2006, Gisela 6 and Gisela 5 yielded about 222% and 144% more 10.5-row+ fruit than Mazzard. The trend in tree productivity on Mazzard, Mahaleb, Gisela 6, and Gisela 5 is presented in Figure 3. The precocity and productivity of the Gisela series is again apparent - early yields were 3 to 6-fold greater than those on Mazzard. Bing productivity on Mazzard has increased every year. This suggests that after 9 years, these trees have not yet reached full production. In contrast, our data suggest that Gisela-rooted Bing trees reached full production in their 4th and 5th leaf.

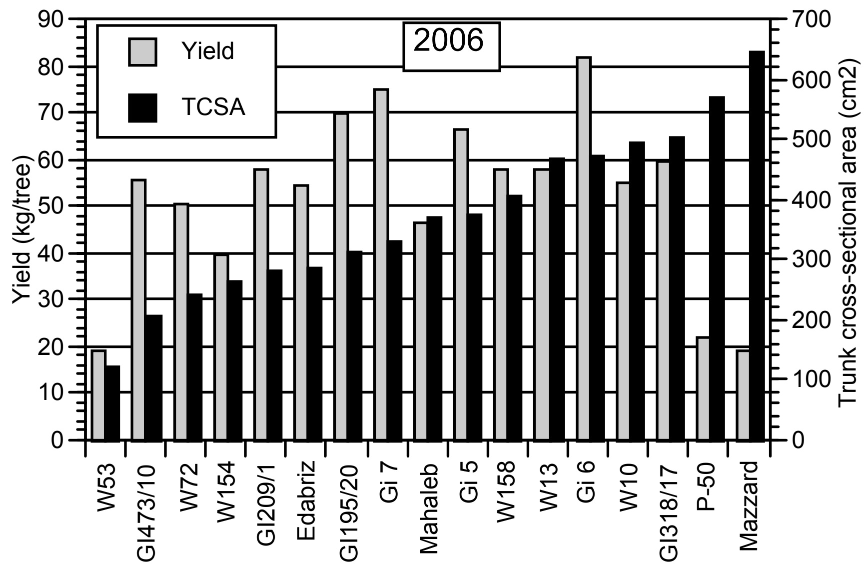

Figure 1. Effect of rootstock on vigor (trunk cross-sectional area, TCSA, black bars) and fruit yield (kg/tree, grey bars) from 9-year-old 'Bing' trees grafted on 17 different rootstocks.

Vigor & quality Vigor varied among rootstocks by more than 5-fold (Fig. 1 & 3). Mazzard is the most vigorous rootstock, W 53 is the least vigorous. Gi 5 and Gi 6 are ca. 58% and 73% the vigor of Mazzard, respectively. P-50, Gi 318/17, Gi 6, W10, and W13 are all vigorous (ca. 75%+ of Mazzard). W 158, Mahaleb, Gi 5, Gi 7, and Gi 195/20 were semi-dwarfing (ca. 50 – 65% of Mazzard). Edabriz, Gi 209/1, W 154, W 72, Gi 473/10, and W 53 are dwarfing rootstocks, reducing TCSA to less than 45% of Mazzard. The tree density of the research orchard is 115 per acre. This is a low density for even the most vigorous rootstocks. It is not known how higher, more appropriate densities would affect tree growth and productivity. However, as we reported previously, yield and precocity are unrelated to vigor (Fig.1). Low-yielding, vigorous rootstocks (i.e., Mazzard and P-50) will not provide growers the early returns on investment or size control necessary to improve labor efficiency, and are not recommended for 'Bing'. However, these rootstocks may be appropriate for very productive and precocious varieties (e.g., 'Chelan', 'Sweetheart'), especially when grown in poor soils.

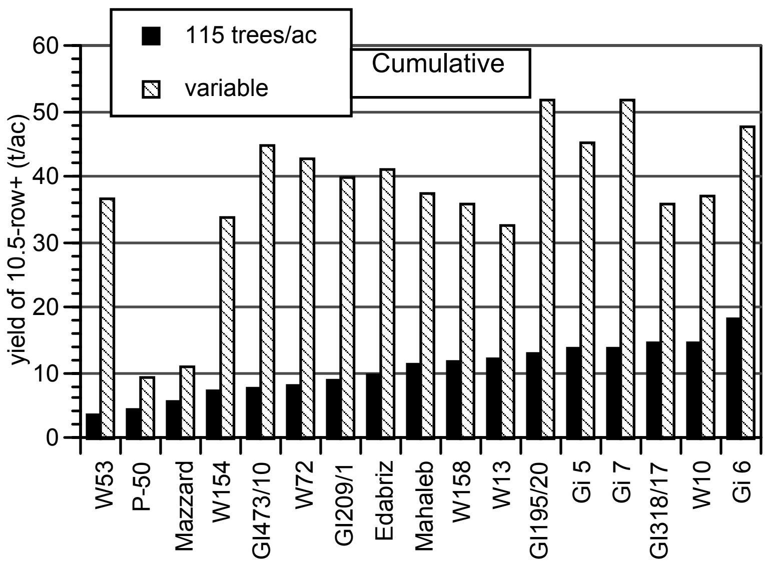

Figure 2. Cumulative yield (2001 to 2006) of 10.5-row and larger 'Bing' fruit (tons/acre) at the test block density of 115 tree/acre and a hypothetical variable density inversely proportional to tree vigor (e.g., Mazzard @ 220 trees/ac; Gisela 5 @ 380 trees/ac; W53 @ 1150 trees/ac).

There are several rootstocks which exhibit moderate – high yield and vigor control (i.e., high yield efficiency) which may be desirable and appropriate for high density, more efficient plantings. In this regard, our analyses suggest almost every rootstock is an improvement upon Mazzard. In a slightly-dwarfing category (70 to 90% of Mazzard), Gisela 6 is the most promising rootstock. In 2006, Gisela 6-rooted trees yielded 82 kg (180 lbs/tree) of fruit that was 9.5 g, 18.0 brix, and ca. 85% 10.5-row and larger (Table 1). This translates into approximately 9.5 tons/ac at the low density of the research orchard. In a semi-dwarfing category (50 to 65% of Mazzard), the most promising rootstock is Gisela 5. In 2006, 'Bing' on Gisela 5 yielded ca. 67 kg (150 lbs/tree) of fruit that was 8.9 g, 18.4 brix, and ca. 75% 10.5-row and larger. At 115 trees/ac, this translates into ca. 7.7 tons/ac.

In 2006, fruit quality overall was good on most rootstocks (Table 1). Fruit weight ranged from a low of 6.8 g on Gisela 473/10 to 11.1 g on Mazzard. Mean fruit weight was 8.9 g. Fruit soluble solids was 18.5 brix, on average, and rootstock had only a subtle effect. Fruit firmness was low in 2006. This is likely due to unseasonably warm temperatures in the days before harvest. Firmness averaged 227 g/mm, down about 23% from the previous season. Percent of fruit that were 10.5-row and larger ranged from a low of 33% (Gi473/10) to 100% (Mazzard). Most rootstocks yielded very few (< 5%) fruit that were smaller than 12-row. Only W53 and Gi473/10 yielded more, 14 and 10%, respectively.

We recorded no clear relationship between fruit yield or yield efficiency and fruit soluble solids or firmness (data not shown). However, there was a clear negative relationship between yield efficiency and fruit weight ($r^2 = 0.69$). In addition, % fruit 10.5-row and larger was related closely and negatively to tree yield efficiency (Fig. 4). This is due to insufficient supply of photosynthate to fruit at high yield efficiency (i.e., high fruit-to-leaf area ratio) and has been reported previously by this lab. Because trees yielded very little fruit that was smaller than 12-row, there was a positive relationship between tree yield efficiency and % 11- and 12-row fruit (Fig. 4). Balanced cropping targets for 2006 can be developed by analysis of these relationships, For example, these data suggest that, to produce a target of no less than 80% 10.5-row and larger fruit, yield should be limited to ca. 0.16 kg per cm^2 TCSA. For Gisela 5, for example, this target translates into approximately 60 kg/tree (0.16 kg cm^{-2}

376 cm^2). Actual yield in 2006 was close to this target at 67 kg. For comparison, on Mazzard, balanced cropping of 0.16 kg/cm^2 would translate into a yield of ca 103 kg/tree. Actual yield from Mazzard-rooted trees was considerably less, at 19.3 kg/tree, suggesting that these trees were very much under-cropped in relation to the capacity of the canopy to support fruit growth.

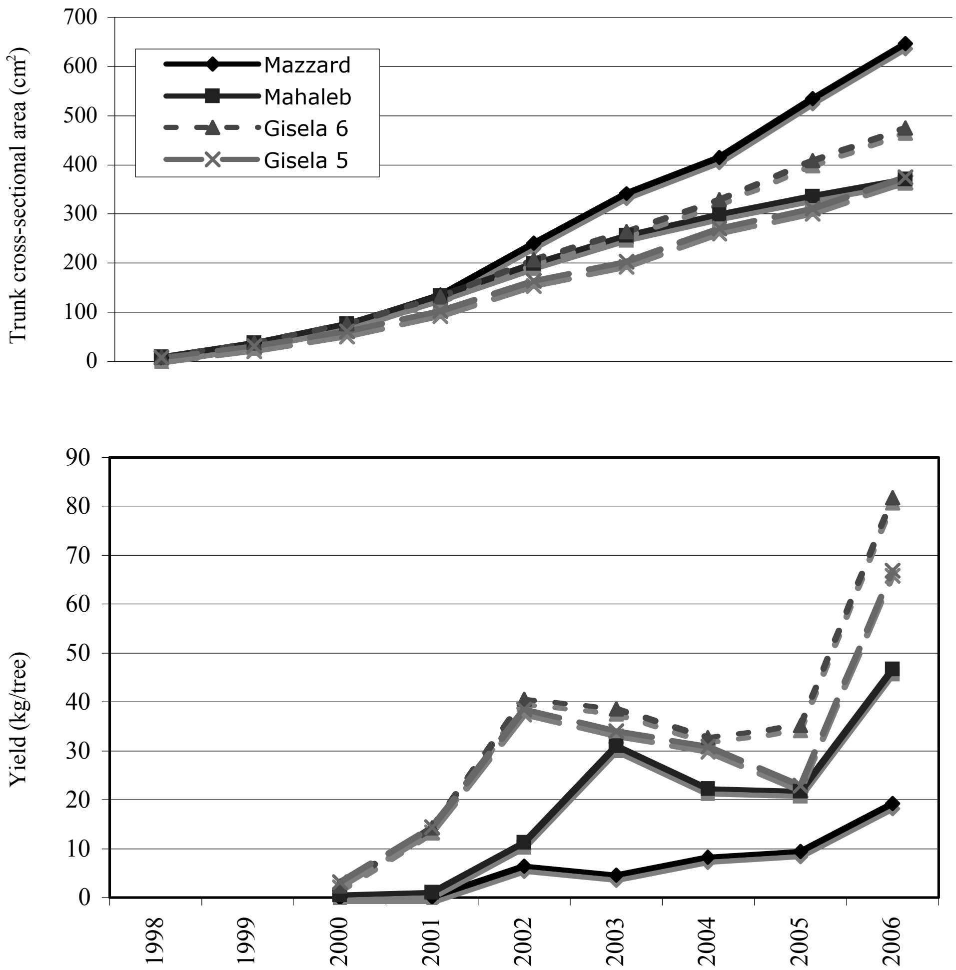

Figure 3. Trend in tree vigor (trunk cross-sectional area) and productivity (kg/tree) of 'Bing' sweet cherry on 4 rootstocks from the 1998 NC-140 trial. Trees were planted in 1998.

In 2005 and 2006, we documented a significant variation in harvest date based on fruit skin color (data not shown). In 2005, 'Bing' on Gi 5, Gi 6, and W158 reached optimum harvest maturity on 22 June while fruit on Mazzard did not reach similar maturity until 1 July. Average harvest date for all rootstocks was 24 June. In 2006, we documented a 4 day variation in harvest maturity. Again, Mazzard-rooted trees were the latest maturing and those on Gi 3, and Gi 473/10 were the earliest to mature. It is not known whether similar discrepancies in harvest maturity would exist for other earlier or later-maturing varieties. However, this result highlights the need to consider rootstock when planning new orchards for a particular harvest season.

Rootstock also affected the date of first and full bloom (data not shown). There was about a four-day (ca. 50 GDD @ base-40) difference between first bloom in Edabriz, Gi 5, W158, and Mahaleb (earliest-blooming, at ca. 680 – 690 GDD) and Mazzard (latest blooming, at 740 GDD). Mazzard-rooted trees were also the last to achieve full bloom, again about 4 days (ca. 70 GDD) later than Gi 5 and Edabriz. At our orchard site, we have not noticed any relationship between first and full bloom dates and frost damage to flowers but in other sites, this may be a concern. We did document in 2005 a significant positive linear relationship ($r^2 = 0.71$) between tree vigor and bloom date (i.e., the more vigorous the tree, the later the bloom).

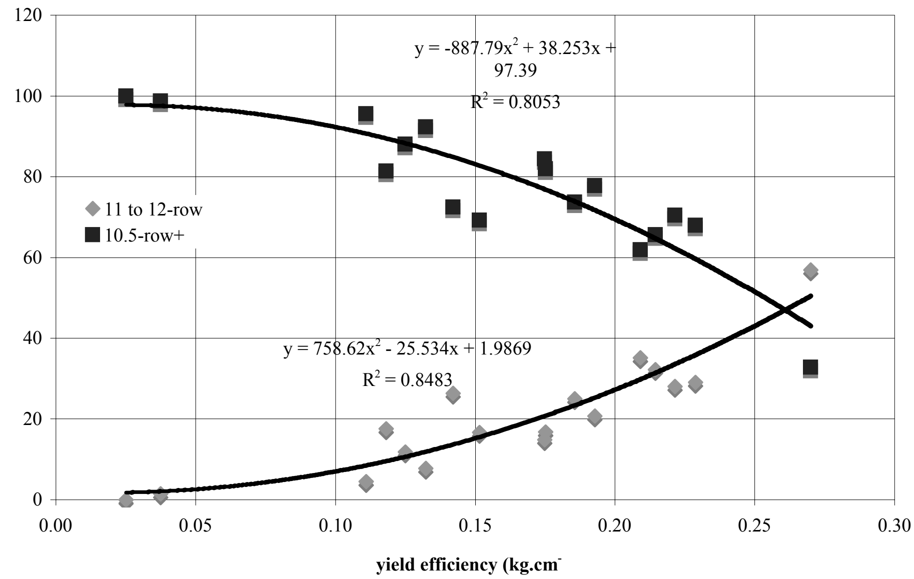

Figure 4. Relationships between tree yield efficiency (kg fruit per cm2 trunk cross-sectional area) and the percent of fruit 10.5-row or larger (black squares) and the percent of fruit 11 to 12-row (grey diamonds) from 9-year-old 'Bing' trees grown on 17 different rootstocks. Each point is a mean of 8 single tree replications per rootstock.

PiKu trial In 2001 we planted an orchard of 16 scion varieties on both PiKu 1 and PiKu 3 rootstocks. 2006 was this orchard's third year of fruiting for most varieties. On PiKu 3, Bing and Selah were the least productive, though, due to poor fruit set overall, yields were low throughout the orchard (Table 1). BlackGold/PiKu1 was the most productive combination, yielding only 2.8 kg (6 lbs) per tree. Several varieties yielded no fruit on PiKu 3 (data not shown). Again in 2005, PiKu 1 was significantly more precocious, out-yielding trees on PiKu 3 by over 7-fold, though this difference was only ca. 2 lbs/tree. In addition, PiKu 1 remains about 40% less vigorous than PiKu 3. Across all varieties, there were significant, albeit subtle, differences in fruit quality between PiKu 1 and Piku 3 in 2005. Fruit firmness and soluble solids were about 6% higher on PiKu 1. Tree mortality was similar for both rootstocks – we have documented ca. 10% tree loss. Particularly poor combinations appear to be Attika/PiKu 3 (75% tree death), Glacier on both PiKus (50% tree death), and Lapins/PiKu 1 (50% tree death).

Fruit quality among scion varieties varied considerably in this third year of production (data not shown). Briefly, Summit, Tieton, Attika, Black Gold, Rainier, Regina, Selah, Sweetheart, and Skeena were among the largest fruit (ca. 10.5 g+ and > 90% 10.5-row and larger) and Sonata, Chelan, and Glacier were the smallest (< 9 g/fruit, less than ca 70% 10.5-row and larger). Sweetheart and Black Gold were the most precocious cultivars, yielding greater than 5 kg (11 lbs) per tree. Overall, productivity is low on these rootstocks, compared to the Gisela series.

Bing, Black Gold, Lapins, Tieton, and Regina were the most vigorous varieties (TCSA > 120 cm^2). Attika, Benton, Celeste, Sonata, and Glacier were the least vigorous (TCSA < 80 cm^2).

Table 1. Effect of rootstock (Piku 1 and 3) on yield and fruit quality of 4-year-old sweet cherry trees. Data are means of 16 scion varieties. Means followed by the same letters within a column are not significantly different (P>0.05).

Rootstock	Date	Weight (g)	°Brix	Firmness (g/mm)	% 11 & 12-row	% ≥10.5-row	Yield(g)	TCSA(cm^2)
2004								
PiKu 1	6/19	8.0a	22.9a	274b	31a	63a	974a	22.7b
PiKu 3	6/18	8.1a	21.1b	296a	25b	66a	406b	36.9a
LSD		0.4	0.9	19	6	8	145	3.6
2005								
PiKu 1	6/26	10.1a	23.8a	347a	8a	91a	1133a	42.2b
PiKu 3	6/28	10.1a	22.4b	327b	11a	88a	152b	72.0a
LSD		0.4	1.1	16	4	5	245	5.6
2006								
PiKu 1	7/1	10.2 b	19.2 a	264 b	13	86	5485 a	74.3 b
PiKu 3	7/2	10.7 a	18.1 b	299 a	9	90	936 b	131.9 a
LSD		0.4	0.6	13.1	4	5	742	7.9

Table 2. Effect of rootstock on 'Bing' fruit yield, quality, tree size, and yield efficiency. Data within a column followed by different letters are significantly different by LSD (P < 0.05).

Rootstock	Vigor (cm^2 TCSA)	Yield (lb)	Yield of 10.5-row+ (lb)	Fruit weight (g)
W53	123.5 g	42.6 g	28.4 g	8.3 cd
Gi473/10	208.4 j	123.1 de	42.1 efg	6.8 e
W72	241.9 ij	111.7 ef	65.1 defg	8.4 cd
W154	264.5 hij	87.9 f	70.7 def	9.1 bcd
Gisela 3	283.4 ghi	128.3 cde	70.8 def	8.1 de
Edabriz	289.7 ghi	120.0 de	96.2 bcd	8.9 bcd
Gi 195/20	315.9 fgh	154.4 abc	110.3 b	8.2 d
Gisela 7	331.8 fg	165.4 ab	114.1 b	8.3 cd
Mahaleb	370.9 g	103.0 ef	75.5 cde	9.2 abcd
Gisela 5	375.8 ef	147.3 bcd	107.4 bc	8.9 bcd
W 158	407.6 de	128.4 cde	97.4 bcd	8.5 cd
W 13	470.0 cd	128.2 cde	118.4 ab	9.7 abc
Gisela 6	475.6 cd	180.3 a	150 a	9.5 abcd
W 10	495.3 c	121.7 de	115.7 b	10.2 ab
Gi 318/17	506.7 bc	132.0 cde	113.8 b	8.4 d
P-50	569.4 b	48.9 g	40.9 fg	9.8 abc
Mazzard	646.2 a	42.5 g	42..3 efg	11.1 a
LSD	72.9	31.1	35.3	1.5