

## **Yield, Fruit Size, Red Color, and Estimated Crop Value in the NC-40 1990 Cultivar/Rootstock Trial in Virginia**

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### ***Abstract***

An NC-140 apple cultivar/rootstock trial was conducted near Blacksburg, VA from 1990 through 1999. In addition to the four cultivars common to all sites ('Golden Delicious', 'Jonagold', 'Empire', and 'Rome'), we also had 'Stayman', and 'York'. Rootstocks were Mark, Ottawa 3 (O.3), Budagovsky 9 (B.9), Malling 9 EMLA (M.9EMLA), and Malling 26 EMLA (M.26EMLA). Our objective in this supplemental study was to evaluate cultivar and rootstock effects on yield, distribution of fruit sizes, and color in order to estimate value of the crop. After eight years of cropping, there were very few significant cultivar x rootstock interactions; therefore, mostly main effects are presented. Fruit size was largest for 'Rome' and 'Jonagold', intermediate for 'Stayman' and 'York', and smallest for 'Golden Delicious' and 'Empire'. Trees on M.26EMLA and M.9EMLA produced somewhat larger fruit than did trees on Mark and O.3. Fruit from trees on B.9 were intermediate in size. Red color was variable, so in spite of significant differences, general conclusions were impossible. Projected value/tree for fresh fruit ('Empire', 'Rome', and 'Stayman') based on yield, fruit size, and red color was greatest for trees on M.26EMLA and M.9EMLA, intermediate for trees on O.3, and lowest for trees on Mark and B.9. In estimated value for processing, 'York' was higher than 'Golden Delicious', and fruit from trees on M26EMLA, O.3, and M.9EMLA were higher in value than those from trees on Mark and B.9.

As apple rootstocks have been evaluated in NC-140 trials, prime attention has been paid to survival, tree size, precocity, yield, and mean fruit size (1, 10, 11). In some cases, there have been data published on fruit quality attributes such as soluble solids levels, starch indices, and maturity ratings (2, 3, 4). However, because of limited time and resources, most of the fruit size data have been based on mean fruit weight determined from a 50-fruit sub-sample per tree (10,11). Unfortunately, mean fruit weight provides no information on either the range or distribution of fruit sizes. Therefore, economic projections of the relative value of the crop from the test trees is impossible.

As a supplement to the 1990 NC-140 Apple Cultivar/Rootstock Trial, we sized all fruit for six of the eight years in which fruit were harvested. In addition, a sub-sample of fruits was evaluated for red color. From a combination of yield data within these two data sets, we estimated crop values.

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## ***Materials & Methods***

This study was a supplement to the 1990 NC-140 Apple Cultivar/Rootstock Trial which was established in 21 sites across North America (1). In addition to the cultivars common to all locations ('Golden Delicious', 'Jonagold', 'Empire', and 'Rome'), we included 'York' and 'Stayman', two regionally important cultivars. Rootstocks were Mark, Ottawa 3 (O.3), Budagovsky 9 (B.9), Malling 9 EMLA (M.9EMLA), and Malling 26 EMLA (M.26EMLA). In Virginia, there were six single-tree replications in a randomized-complete-block/split plot design, with cultivar and replication as the whole plot, and rootstock as the split-plot. Trees were spaced at 2.5 x 5.0 m, and were trained as modified slender spindles. Support was provided by a 3 m bamboo stake supported by a single wire at 2.5 m. When judged to be commercially mature, all fruit of each cultivar were harvested in a single harvest. Fruits from individual trees were sized with a chain sizer (1992-1993) or a weight sizer (1996-1999). The fruits were sized as follows: <5.7cm, 5.8-6.2cm, 6.3-6.9cm, 7.0-7.5cm, 7.6-8.9cm, >8.9cm. In some years and with selected cultivars, the percentage of the surface colored red was estimated visually for each of 20 fruit per tree. Because of the similarity of prices for "bag" size (6.3-6.9 cm dia.) and "tray pack" size (>7 cm dia.) fruit, we assigned juice prices for fruit <6.3 cm dia. and fresh market prices for fruit > 6.3 cm dia. For the fresh fruit cultivars we used the following color minimums for suitability for packing: 'Empire' 70% red, 'Stayman' 80% red, and 'Rome' 90% red. Value was not estimated for 'Jonagold', because red color was inadequate for marketing of fresh fruit and it is not desirable for processing. With 'York' and 'Golden Delicious' we used three size categories to reflect typical processing prices (<6.3cm, 6.3-7cm, and >7cm). 'Golden Delicious' value was calculated for processing rather than the fresh market because of excessive russetting.

To estimate kg of marketable fruit for the fresh market, the cumulative yield (kg/tree) was multiplied by the proportion of fruit >6.3cm and the proportion of fruit meeting the specified red color minimum. The kg of marketable fruit was multiplied by a price of \$0.62/kg. To this was added the value of "juice apples" (fruit <6.3 cm) valued at \$0.088/kg. (Marketable fruit price was based on data for the Appalachian District, from autumn 2000 issues of *The Packer*; juice price, personal communication, National Fruit Products Co., Winchester, Va. 22604)

To estimate value of 'York' and 'Golden Delicious' for processing, the cumulative yield per tree in the three sizes was multiplied by the respective prices of \$0.22/kg for fruit > 7cm, \$0.176/kg for fruit 6.3-7cm, and \$0.088 for fruit <6.3cm (Personal communication, National Fruit Products Co.).

## ***Results & Discussion***

For cumulative yield the cultivar x rootstock interaction was not significant, so the main effects for cultivar and rootstock are presented (Fig.1). Cumulative yield per tree was greatest for 'Rome', intermediate for 'Jonagold', 'Stayman', and 'York' and lowest for 'Golden Delicious' and 'Empire'. Yields were highest for trees on M.26EMLA and M.9EMLA, intermediate for trees on O.3, and lowest for trees on B.9 and Mark (Fig. 1B). The yields in our trial were well above the twelve-state means, but the trends among rootstocks were similar (1).

Overall, fruit size was excellent (less than 10% of fruit < 6.3 cm dia in all treatments). The

cultivar x rootstock interaction was not significant for the percentage of fruit in each size, so main effects for cultivar and rootstock are presented (Fig.2). ‘Jonagold’ and ‘Rome’ produced the lowest percentage of small (<6.3 cm) and medium (6.3-7.5 cm) and the highest percentage of large (>7.6 cm) fruit (Fig.2A). ‘Stayman’ and ‘York’ were intermediate in all sizes. Overall, the smallest fruit were ‘Empire’ and ‘Golden Delicious’. ‘Empire’ peaked in the medium category, whereas ‘Golden Delicious’ peaked in the large size.

The effects of rootstocks on fruit size were somewhat less distinct than the effects of cultivars, but were significant. Trees on M.26EMLA, M.9EMLA, and B.9 produced the lowest percentage of small fruit (Fig, 2B). Trees on O.3 yielded the largest percentage of medium sized fruit. All other rootstocks were similar. In the large size, the percentages were highest for M.26EMLA and M.9EMLA and declined as follows: B.9 > Mark > O.3. In a one year study with ‘Cortland’ and two strains of ‘McIntosh’, Granger et al.(8) divided all fruit of each cultivar into six sizes. Compared to thirteen other rootstocks (but not including M.9 or M.9EMLA), trees on M.26EMLA produced the greatest proportion of large fruit. Results from multiple trials, which included either most or all of the rootstocks included here showed little effect of rootstock on fruit size (5, 6, 9, 10). Barritt et al. (7) reported that, with ‘Golden Delicious’, and ‘Delicious’, fruit from trees on Mark were smaller than those from trees on M.26EMLA. With ‘Granny Smith’, however, there was no difference in fruit size between Mark and M.26EMLA.

There were differences in fruit red color on trees on different rootstocks, but the effects were not consistent across cultivars (Table 1). Fruit from ‘Empire’ trees on Mark had less red color than fruit from trees on B.9, M.9EMLA, and M.26EMLA. ‘Stayman’ fruits were redder from trees on O.3 than from trees on Mark, M.9EMLA, and M.26EMLA. Red color of ‘Rome’ fruit was not significantly affected by rootstock. We omitted ‘Jonagold’ from these calculations, because this cultivar is poorly adapted to Virginia conditions and red-color development was consistently too poor to justify packing. In spite of some differences, the effect of rootstock on red color development was rather variable among cultivars and therefore it was of only minimal importance in this study. In general, our data agree with those from earlier studies utilizing ‘Delicious’ (3, 4) and ‘Macspur McIntosh’ (9). It is quite probable that a 20 fruit sample is inadequate to evaluate color, much like a 50 fruit sample for the evaluation of fruit size. Were we comparing dwarf trees, such as those in this study, with semi-dwarf or standard sized trees, one would anticipate much larger differences, strictly due to increased shading on larger trees.

The estimated cumulative value of fresh-market fruit was influenced by cultivar, rootstock, and the interaction between cultivar and rootstock (Table 2). Overall, crop value was highest for ‘Rome’, intermediate for ‘Stayman’, and lowest for ‘Empire’, reflecting both total yield (Fig.1) and fruit size (Fig.2). Crop value was highest for trees on M.26EMLA and M.9EMLA, intermediate for trees on O.3, and lowest for trees on Mark and B.9, which reflects yield differences (Fig. 1B) more than fruit size (Fig.2B). The significant cultivar x rootstock interaction likely resulted from the relatively high value of ‘Rome’/Mark and ‘Stayman’/O.3, and the relatively low value of the crop of ‘Rome’/O.3.

With the value data for ‘Golden Delicious’ and ‘York’ for processing, there were significant effects of cultivar and rootstock, but the cultivar x rootstock interaction was not significant (Table 3). Estimated value of ‘York’ was greater than that for ‘Golden Delicious’ reflecting differences in both

total yield (Fig.1) and fruit size (Fig.2). The higher crop value for fruit from trees on M.9EMLA, O.3, and M.26EMLA largely reflected differences in yield (Fig.1) rather than fruit size (Fig.2).

The amount of red color is of prime concern in the marketing of fresh market apples, but in this study there were not consistent effects of rootstock on red color, however, we question the adequacy of our sample size. To estimate the cumulative value of the crop per tree, various assumptions must be made and these are obviously open to debate. It is our opinion, however, that regardless of the assumptions made, the estimates enable us to make relative comparisons among treatments which adds considerably to the usefulness of such studies.

### ***Summary & Conclusions***

Data in our study indicate sizeable differences in estimated crop value depending on rootstock as well as cultivar. In estimating crop value, it is readily apparent that a vitally important consideration is fruit size distribution as well as total yield. For this reason, it is strongly recommended that whenever possible, fruit from rootstock studies be sized on a grader to enable a crop-value estimation.

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Table 1. Rootstock effects on red color of three cultivars.

Rootstock	Cultivar		
	Empire <sup>z</sup> (> 70% red)	Stayman <sup>y</sup> (> 80% red)	Rome <sup>x</sup> (> 90% red)
M.26 EMLA	81 a <sup>w</sup>	70 b	66
M.9 EMLA	80 a	68 b	68
B.9	81 a	75 ab	68
Mark	66 b	66 b	78
O.3	74 ab	86 a	57
P-value	0.016	0.015	0.190

<sup>z</sup>Means for 1993, 1994, 1995, 1997 (year x rootstock P = 0.23).

<sup>y</sup>Means for 1993, 1996, 1997 (year x rootstock P = 0.53).

<sup>x</sup>Means for 1993, 1997 (year x rootstock P = 0.95).

<sup>w</sup>Mean separation within columns by DMRT (P = 0.05).

Table 2. Estimated cumulative dollar value per tree for three cultivars as fresh fruit (1992-1999)<sup>z</sup>.

Rootstock	Cultivar			Mean
	Empire	Rome	Stayman	
M.26 EMLA	182.83 <sup>y</sup>	239.62	199.91	\$207.45 a
M.9 EMLA	159.62	218.61	209.74	\$195.99 a
B.9	106.00	137.27	110.66	\$117.98 c
Mark	80.61	154.18	80.07	\$104.96 c
O.3	154.43	156.34	204.22	\$172.57 b
Mean	\$136.70 c	\$182.06 a	\$160.92 b	

<sup>z</sup>Crop \$ value calculated as follows: kg (< 6.3 cm) @ \$0.088/kg + kg (> 6.cm) @ \$0.62/kg.

<sup>y</sup>Mean separation among overall rootstock or overall cultivar means by DMRT (P = 0.05).

ANOVA: cv P < 0.0001; rs P < 0.0001; cv x rs P = 0.0034

Table 3. Estimated cumulative dollar value per tree of ‘York’ and ‘Golden Delicious’ for processing (1992-1999)<sup>z</sup>.

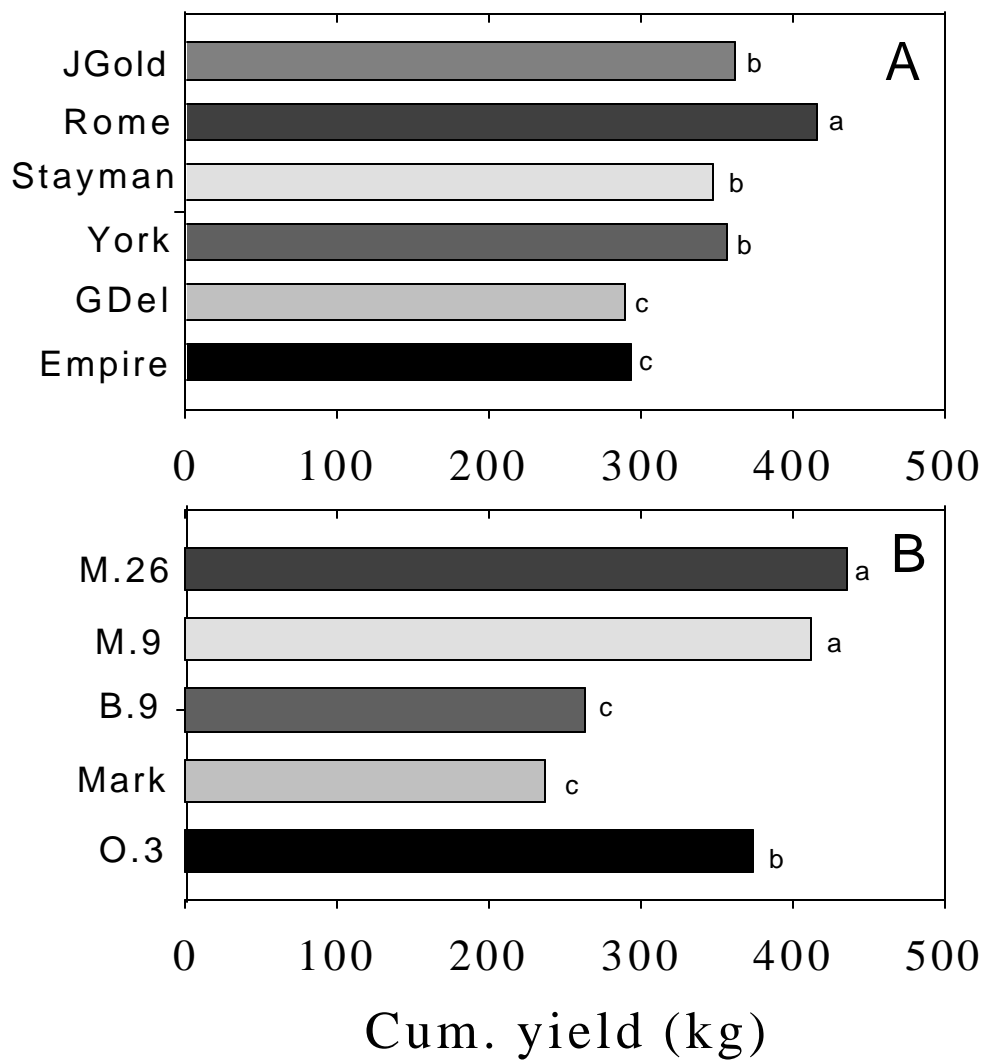
Rootstock	Cultivar		Mean
	Golden Del.	York	
M.26 EMLA	72.76 <sup>y</sup>	93.06	\$82.91 a
M.9 EMLA	70.99	83.46	\$77.79 a
B.9	48.38	56.95	\$52.66 b
Mark	38.69	50.62	\$44.66 b
O.3	61.85	89.13	\$75.49 a
Mean	\$58.10 b	\$74.64 a	

<sup>z</sup>Crop value calculated as follows: kg (< 6.3 cm) @ \$0.088/kg + kg (6.3-7.0 cm) @ \$0.176/kg + kg (> 7 cm) @ \$0.22/kg.

<sup>y</sup>Mean separation among overall rootstock or overall cultivar means by DMRT (P =0.05).

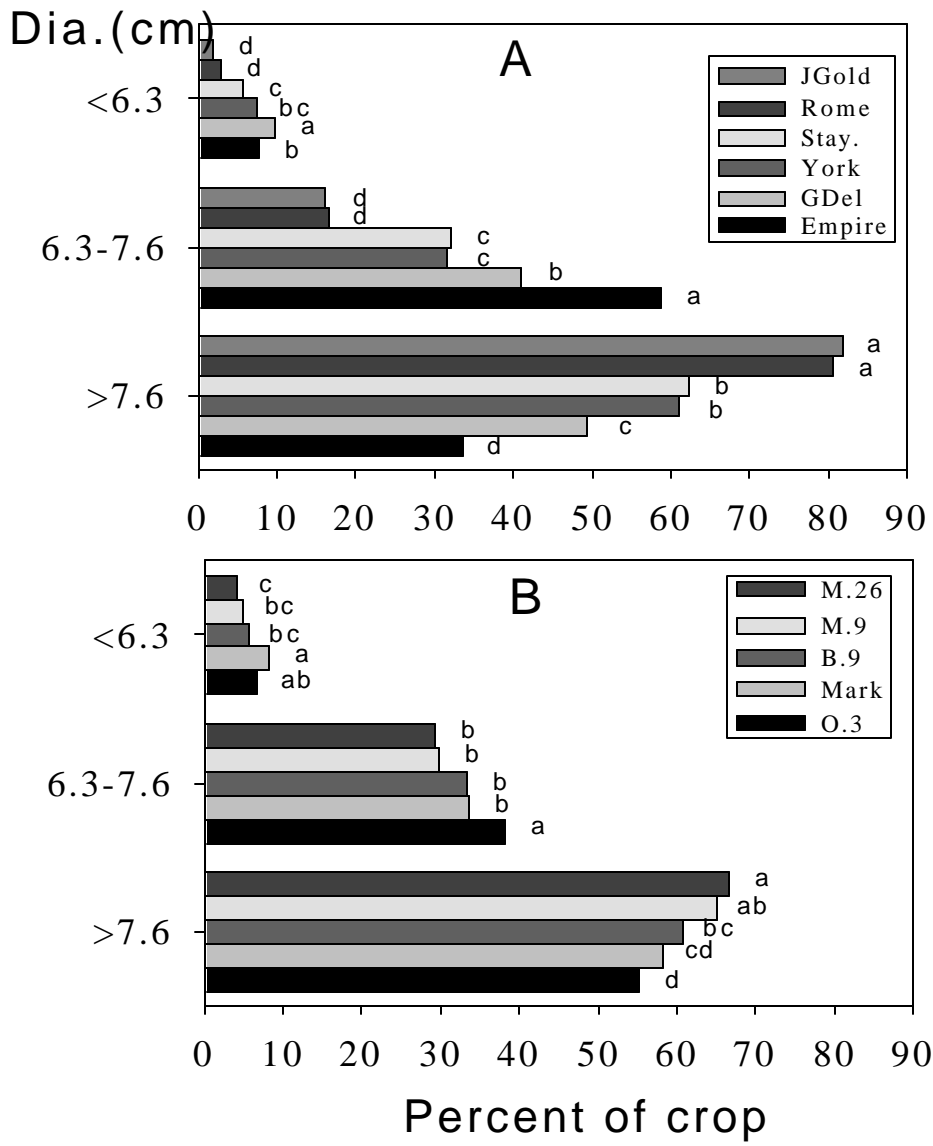
ANOVA: cv P<0.001; rs P<0.001; cv x rs P=0.2246





**Figure 1**

Fig. 1. Cumulative yield (kg/tree) from 1992-1999 as affected by cultivar (A) and rootstock (B). ANOVA: cultivar  $P < 0.0001$ , rootstock  $P < 0.0001$ , cv x rs  $P = 0.1074$



**Figure 2**

Fig.2 Percent of crop in each of three sizes as affected by cultivar (A) and rootstock (B). Data are means for 1992, 1993, 1996-1999.

ANOVA: Size 1 (<6.3 cm) cultivar  $P < 0.0001$ , rootstock  $P < 0.0001$ , cv x rs  $P = 0.0531$ .

Size 2 (6.3-7.6 cm) cultivar  $P < 0.0001$ , rootstock  $P < 0.0005$ , cv x rs  $P = 0.9878$ .

Size 3 (>7.6 cm) cultivar  $P < 0.0001$ , rootstock  $P = 0.0001$ , cv x rs  $P = 0.8589$ .