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Early Performance of Four Apple Cultivars, Supported or Free Standing, on Mark Rootstock[1]

PRESTON K. ANDREWS[2] AND CURT R. ROM[3]

Abstract

'Nicobel Jonagold,' 'Imperial Gala,' 'Early Red One Delicious' and 'Ultragold' apple trees on Mark rootstock were planted at Pullman, WA in 1988. Trees were either free standing or supported with a 60 or 180 cm post above ground. After 5 years, 'Jonagold' trees had the largest trunk cross-sectional area (TCSA), followed by 'Imperial Gala,' 'Early Red One' and 'Ultragold.' The cumulative yields/tree were almost 45 kg for 'Jonagold,' 30 kg for 'Imperial Gala' and about 15 kg for both 'Early Red One' and 'Ultragold.' Biennial bearing was observed in 1991 for 'Jonagold' and 'Ultragold' trees. 'Imperial Gala' trees exhibited the most consistent cropping. In the fourth and fifth years, the mean weight of fruits produced on 'Jonagold' and 'Early Red One' was >200 g. The largest mean fruit weight was 249 g for 'Early Red One' in 1992, due to low yields and fruit numbers per tree. The mean fruit weight of 'Imperial Gala' averaged 165 g in the fourth and fifth years. 'Ultragold' fruit were consistently small. The yield efficiencies of all cultivars were <1.0 kg fruit/cm^2 TCSA, due to the large TCSAs. Crop density exceeded 9 fruit/cm^2 TCSA for 'Ultragold' trees in 1990, but generally was between 2-4 fruit/cm^2 TCSA. Supporting the trees with a post had no effect on any of the above parameters. There was more mortality among free-standing trees than supported trees in the first 3 years of the planting. More than 25% of the 'Jonagold' trees died, mostly due to breakage at the graft union. Less than 5% of each of the other cultivars died. Half of the 'Jonagold' trees which were lost, however, were supported. Even though support did not improve tree growth or productivity in this experiment, it is recommended that trees on Mark rootstock be supported and that careful crop management of precocious scion cultivars be observed in the early years of the planting.

Introduction

The Mark (MAC.9) apple rootstock has rapidly gained popularity for its dwarfing and precocity-inducing characteristics since it was patented in 1980 and released for commercial sale by Michigan State University in 1986 (4, 16). In the early years of the national NC-140 rootstock trial, 'Starkspur Supreme Delicious'/Mark trees demonstrated high yield efficiency and production potential (12). Trees with this spur-type cultivar, however, exhibited poor growth and senescence after 10 years in this trial (16, 18). In another Mark rootstock trial with 'Empire' and 'Golden Delicious,' tree size was similar to trees on M.9 rootstock after 10 years (9, 13).

Because the Mark rootstock was reported to have a well-anchored root system (3, 4), it was originally assumed not to require external support (3, 4, 17). An early planting of 'Red Prince Delicious'/Mark trees in Michigan was productive in its first 5 years without support (5, 16). At the Ontario, Canada site of the NC-140 trial, free-standing 'Starkspur Supreme Delicious'/Mark trees showed no tendency to lean after 7 years, whereas trees on M.9 and M.9 EMLA required support to avoid severe leaning (6). In a fine sandy loam soil in Michigan, however, 10-year-old 'Starkspur Supreme Delicious'/M.26 EMLA and M.9 EMLA trees had greater root densities than the same cultivar on Mark (7).

Little is known about the performance of supported versus free-standing trees on Mark rootstocks other than for 'Starkspur Supreme Delicious' in the NC-140 trial. Support did not increase tree growth, yield or yield efficiency after 9 years with this spur-

[1]Hort/LA Paper No. 91-6, Project 0937, College of Agriculture and Home Economics Research Center, Pullman, Washington 99164-6420, U.S.A. [2]Department of Horticulture and Landscape Architecture, Washington State University, Pullman, Washington 99164-6414 (USA).
[3]Department of Horticulture, 316 Plant Science Building, University of Arkansas, Fayetteville, AR 72701 (USA).

type cultivar (13); however, trees for which support was provided were planted one year later than free-standing trees.

The purpose of this research was to determine the effects on growth and productivity of supported versus free-standing trees with scion cultivars of different vigor and precocity potential on Mark rootstock.

Materials and Methods

Trees of 'Nicobel Jonagold,' 'Imperial Gala,' 'Early Red One Delicious' (standard type), and 'Ultragold' on Mark rootstock were obtained from Treco (Woodburn, OR), Willow Drive Nursery (Ephrata, WA), Van Well Nursery (Wenatchee, WA) and Stark Bro's Nursery (Louisiana, MO), respectively. Forty-five trees of each cultivar were planted in a Palouse silt loam (≥1.5 m deep) on 13 April 1988 at 1.52 X 4.88 m spacing (1345 trees/ha) in plots of 3 trees/cultivar at the Washington State University R. B. Tukey Orchard, Pullman, WA. Within each plot trees were either free-standing or supported by I0-cm diameter wooden posts 60 or 180 cm above ground. The experimental design was a split-plot with 4 cultivars as the main plots arranged in a randomized complete block design with the 3 support treatments as subplots, resulting in 15 replications.

After planting, the central leader was headed at 1 m above the graft union, limbs with narrow branch angles were removed, and all remaining limbs were shortened to about 40 cm. The central leaders of supported trees were tied to the post with plastic tape throughout the experiment. Each tree was fertilized with 45 g N as $(NH_4)_2NO_3$ broadcast within the dripline and irrigated immediately after planting. In each subsequent year, each tree was fertilized with an additional 45 g N. The initial trunk cross-sectional areas (TCSA) were determined after planting by measuring the diameter of the trunks 25 cm above the graft unions. In subsequent years TCSA was determined from circumference.

After settling, graft unions were 1-2 cm above the soil surface. Trees were irrigated as necessary with overtree impact sprinklers. Routine, commercial pest management practices were utilized. All trees were trained as central-leader. Fruits were hand thinned to 1 fruit/cluster spaced approximately 10 cm apart about 3 weeks after full bloom, except in 1990 when thinning was omitted. The yields and fruit numbers per tree were measured annually. The yield efficiency (kg fruit/cm^2 TCSA) and crop density (fruit number/cm^2 TCSA) of each tree were calculated from measurements of TCSA at the end of the season and yields and fruit numbers, respectively. Tree mortality also was assessed annually.

All data except tree mortality were analyzed as a general linear model by analysis of variance or correlation analysis. Tree mortality was analyzed by survival analysis using Peto & Peto's Wilcoxon test (11). The initial TCSA

Table 1. Trunk cross-sectional area (TCSA) of 4 scion cultivars on Mark rootstock at planting in April 1988, in November 1992, and the change (Δ) over these 5 growing seasons.

Cultivar	TCSA (cm^2)[z]		
	1988	1992	Δ
'Jonagold'	2.04 a[y]	43.06 a	41.02 a
'Imperial Gala'	1.37 b	36.36 b	34.99 b
'Early Red One'	1.03 c	30.84 c	29.81 c
'Ultragold'	1.48 b	20.27 d	18.79 d

[z]Measured 25 cm above the graft union.
[y]Mean separation within columns by Tukey's test at $P \leq 0.05$.

was tested as a covariant, but since the analysis of covariance was non significant, the adjusted means were not used.

Results

'Jonagold' trees had the largest TCSA at planting and after 5 years (Table 1). 'Early Red One' were the smallest at planting, but were larger than 'Ultragold' in 1992.

'Jonagold' had the highest yields/tree in 1990 and 1992, but very low yield/tree in 1991 (Fig. 1). 'Ultragold' also had low yield/tree in 1991; however, the yield/tree of 'Imperial Gala' was high in that year. 'Early Red One' had low yield/tree in 1992. Only 'Ultragold' and 'Jonagold' produced any fruit in 1989.

'Jonagold' and 'Imperial Gala' produced the most cumulative fruits/tree (data not presented). 'Ultragold' produced significantly more cumulative fruits/tree than 'Early Red One.'

'Early Red One' trees produced the largest fruit of any cultivar in 1990 and even larger fruit in 1991 and 1992 (Table 2). 'Jonagold' fruit were >200 g in 1991 and 1992, despite the heavy yield in the latter year. After producing smaller fruit in 1990, 'Imperial Gala' fruit averaged 165 g in 1991 and 1992. 'Ultragold' fruit were the smallest in 1990 and 1991. In 1990 and 1991, there were significant ($P < 0.05$) negative correlations between the mean fruit weights and crop densities of 'Ultragold' ($r = -0.72$ and -0.66, respectively) and 'Early Red One' trees ($r = -0.49$ and -0.79, respectively). There were

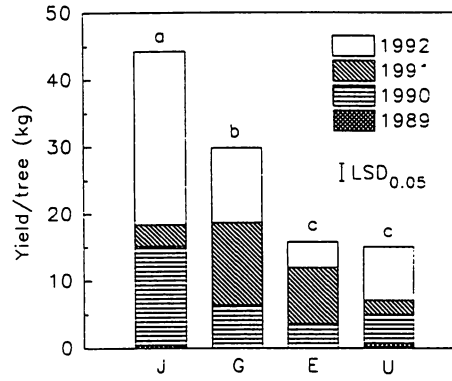

Figure 1. Yield per tree for four scion cultivars on Mark rootstock in 1989-1992. J = 'Jonagold,' G = 'Imperial Gala,' E = 'Early Red One' and U = 'Ultragold.' Different letters above each bar indicate significant differences in the cumulative yield per tree separated by Tukey's test at $P \leq 0.05$.

significant negative correlations between mean fruit weights and crop densities for 'Jonagold' trees in 1990 ($r = -0.45$), and for 'Imperial Gala' trees in 1991 ($r = -0.70$).

'Jonagold' trees had the highest yield efficiency in 1990 and 1992 (Fig. 2A), averaging about 0.7 kg fruit/cm^2 TCSA in those years. 'Imperial Gala' trees had consistent yield efficiencies of about 0.4 kg fruit/cm^2 TCSA in 1990-1992. Both 'Jonagold' and 'Ultragold' had low yield efficiencies in 1991, and 'Early Red One' had a low yield efficiency in 1992.

'Ultragold' trees had the highest crop density in 1990 (Fig. 2B), which was partly reflected in the very small fruit weights (Table 2). 'Jonagold' trees ex

Table 2. Mean fruit weight (g) of 4 scion cultivars on Mark rootstock in 1990-1992.

Cultivar	Mean fruit weight (g)			
	1990	1991	1992	Mean[y]
'Jonagold'	147 cd[z]	241 a	224 a	197 a[x]
'Imperial Gala'	111 e	167 bc	163 bcd	147 b
'Early Red One'	177 b	229 a	249 a	210 a
'Ultragold'	81 f	138 d	161 bcd	111 c

[z]Mean separation in rows and columns 1990 through 1992 by Tukey's test at $P \leq 0.05$.
[y]Mean of 1990-1992.
[x]Mean separation in this column by Tukey's test at $P \leq 0.05$.

hibited fluctuating crop densities between 1990 and 1992 (Fig. 2B). 'Imperial Gala' trees had their highest crop density in 1990, which progressively declined in 1991 and 1992. The crop densities of 'Early Red One' were consistently low.

There were no significant differences ($P < 0.05$) in cumulative TCSA increment, yield and fruit number/tree, mean fruit weight, yield efficiency and crop density between support treatments (data not presented). In both 1991 and 1992, trees supported with posts 180 cm above ground had yield efficiencies of 0.39 kg fruit/cm^2 TCSA, which were significantly higher than the 0.27 and 0.32 yield efficiencies of free-standing trees in these years.

Tree mortality varied significantly ($P < 0.05$) between cultivars and support. 'Jonagold' trees demonstrated increasing mortality each year, significantly greater in 1989-1992 than the <5% mortality experienced by the other cultivars (Fig. 3A). Free-standing trees had significantly greater mortality than supported trees, especially during 1990 when the yield efficiencies and crop densities were highest (Fig. 3B). Surprisingly, there was no significant cultivar x support interaction. Even for 'Jonagold' trees, which experienced >25% mortality, one-half of the trees that died were supported. Although tree mortality was distributed throughout the experimental block, more severe leaning occurred on the windward side. While 88% of the total tree mortality was due to either graft breakage or being blown over, most graft breakage occurred to 'Jonagold' trees.

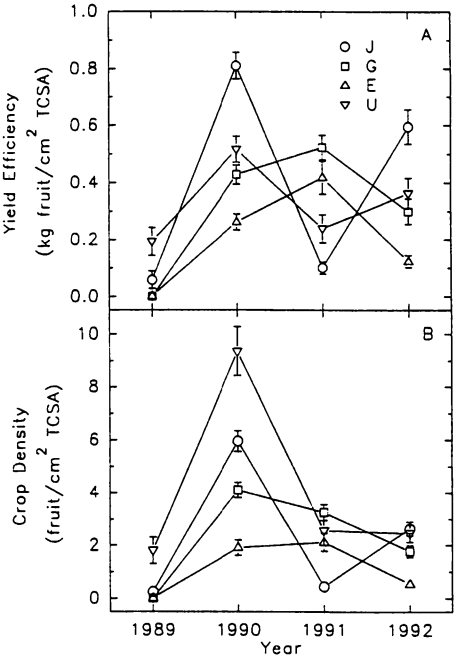

Figure 2. Yield efficiency (A) and crop density (B) for 'Jonagold,' 'Imperial Gala,' 'Early Red One' and 'Ultragold' scion cultivars on Mark rootstock in 1989-1992 (see Fig. 1 for cultivar abbreviations). Error bars indicate standard error of the means at P = 0.05.

Discussion

The trunk sizes (TCSAs) for 'Jonagold,' 'Imperial Gala' and 'Early Red One' after 5 years (Table 1) were larger than 'Starkspur Supreme Delicious'/Mark trees at any of the NC-140 sites during the first 6 years of that trial (12). Even after 10 years, the spur-type 'Starkspur Supreme Delicious' trees had a smaller TCSA at all NC-140 sites (14) than 5-year-old 'Jonagold'/Mark trees in this planting (Table 1). Greater vigor would be expected from a triploid cultivar such as 'Jonagold.' In a 1986 planting at Wenatchee, WA, spur-type 'Redchief Delicious'/Mark trees had similar TCSAs after 4 years as the more vigorous 'Granny Smith' cultivar on the same rootstock (2). The 'Ultragold' scion cultivar, which is considered as vigorous as 'Jonagold' (20), were the smallest of the four cultivars tested (Table 1). The smaller average size of 'Ultragold' trees, however, was partly accounted for by the large proportion of stunted trees of this cultivar. 'Ultragold' trees had the highest crop density of all cultivars in 1989 and 1990 (Fig. 2B). Trees may have been stunted due

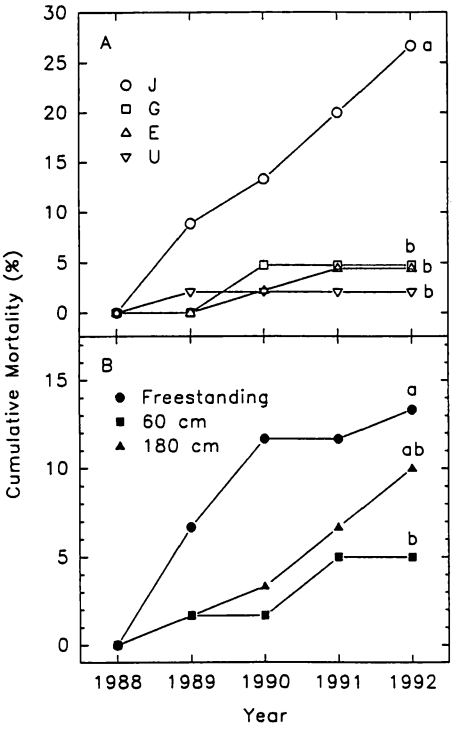

Figure 3. Cumulative mortality of 'Jonagold,' 'Imperial Gala,' 'Early Red One' and 'Ultragold' scion cultivars (A) on Mark rootstock (see Fig. 1 for cultivar abbreviations), and trees freestanding or supported with posts 60 and 180 cm above ground (B) in 1988-1992. Different letters indicate significant differences in cumulative mortality by survival analysis using Peto & Peto's Wilcoxon test ($P < 0.05$).

to the presence of these relatively large crop loads.

The apparent preference of Mark rootstock for heavy soils (16) and its greater relative sensitivity to water stress (8) may account for differences in growth between sites. Variations in nursery tree quality, cultural practices, climates and soils may override differences in vigor inherent among scion cultivars. Mark may be more sensitive to these factors than other rootstocks, which may account for its variability in performance.

Yields/tree varied between cultivars and years (Fig. 1). The cumulative yields/tree of both 'Jonagold' and 'Imperial Gala' after 5 years were as high or higher than the 6-year cumulative yields/tree of both 'Starkspur Supreme Delicious'/Mark in the NC-140 trial (12) and 'Redchief Delicious,' 'McIntosh,' 'Cortland' and 'Empire' on Mark in Maine (19). The cumulative yield of 'Jonagold' after just 5 years was only slightly less (Fig. 2) than 'Empire' and 'Golden Delicious' on Mark in Ohio after 10 years (9). The cumulative yields/tree of 'Early Red One' and 'Ultragold' were about 15 kg after 5 years (Fig. 1), which were similar to the average cumulative yield/tree of 'Starkspur Supreme Delicious'/Mark during the first three crops in the NC-140 planting (13).

Both 'Jonagold' and 'Ultragold' exhibited a biennial bearing habit (Fig. 1), as also was observed in young plantings of 'Golden Delicious,' 'Empire' and 'Redchief Delicious' on Mark in Ohio and Maine (9, 19). Consistent annual yields were exhibited by 'Imperial Gala' in this planting (Fig. 1), and by 'McIntosh' and 'Cortland' in Maine (19). Since the Mark rootstock promotes precocity, caution should be exercised with productive scion cultivars so that over cropping is avoided in the early years of the planting. Although possible over cropping of 3-year-old 'Jonagold' trees in 1990 (Fig. 1) had no apparent adverse effect on tree growth (Table 1), a spur-type cultivar on Mark in the NC-140 trial has resulted in stunting which was probably exacerbated by the potential of Mark to promote spur production and wide branch angles (9, 10, 13, 17, 18).

Mean fruit weights were small for all cultivars in the third year (i.e. 1990) of this planting (Table 2). The mean weight of 'Jonagold' fruit was >200 g in both the light crop year of 1991 and the heavy crop year of 1992. 'Early Red One' also produced fruit >200 g in 1991 and 1992. There was a highly significant ($P < 0.01$) negative correlation between mean fruit weight and

crop density for all cultivars in the 1990 third-leaf year (r = -0.59), indicating that cropping was sufficiently excessive to reduce fruit size in that year.

The yield efficiencies of 'Jonagold' and 'Ultragold' fluctuated greatly (Fig. 2A), in response to lower yields in 1991 due to biennial bearing. The yield efficiencies of 'Imperial Gala' and 'Early Red One' increased to 0.5 and 0.4 kg fruit/cm^2 TCSA, respectively, by 1991, but decreased in 1992. This was due to a greater increase in TCSAs relative to yields. The yield efficiencies of the Mark-cultivar trial planted in Maine ranged from 0.43-0.87 kg fruit/cm^2 TCSA in the sixth year (19). Although these yield efficiencies were similar to those in this planting, the final TCSAs and cumulative yields/tree were about one-half as large in Maine. The yield efficiencies of 'Empire' and 'Golden Delicious' on Mark averaged 2.20 and 2.41 kg fruit/cm^2 TCSA between the third and seventh years in Ohio (9). These higher yield efficiencies were again the result of smaller TCSAs.

Providing support for the trees had no significant effect on tree size or yield (data not presented). No significant increases in yield or yield efficiency from support of 'Starkspur Supreme Delicious'/Mark trees were reported in the NC-140 rootstock trial (13).

Mortality of 'Jonagold' trees accounted for 70% of total mortality during the 5 years of this trial (Fig. 3A). One-half of the 'Jonagold' trees which succumbed, however, were supported, and 67% of those trees were supported by the taller 180-cm post. Mortality of 'Empire' and 'Golden Delicious' trees on Mark in Ohio were 17 and 50%, respectively, after 10 years (9). Although the causes of mortality were not reported, these trees were unthinned and not supported in their early years. Despite the fact that loss of 'Starkspur Supreme Delicious'/Mark trees in the NC-140 trial could not be attributed to lack of support, less mortality occurred to supported Mark trees in this experiment (Fig. 3B).

It has been recommended that Mark rootstocks with more precocious scion cultivars and with vigorous triploid scions be supported (15, 16). Graft incompatibility between triploid cultivars, such as 'Jonagold,' and Mark rootstock has been reported previously (16) and occurred in both free-standing and supported trees in this experiment. Indeed, tree support is recommended with any high-density planting on dwarfing rootstock (1), and recent rootstock trials reflect this opinion (2). Due to the tendency for Mark rootstock to promote horizontal branch orientation, increased spur production and early yields, the crops of precocious scion cultivars should be carefully managed in young plantings to prevent over cropping and insufficient tree vigor.

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Apple Accessions of Low Priority Targeted for Removal from The National Plant Germplasm System

PHILIP L. FORSLINE[1] AND ROGER D. WAY[2]

The National Germplasm Repository (NGR) for Apple and Grape in Geneva, NY is part of the National Plant Germplasm System (NPGS). It was established in 1983 after initial planning in the 1970s (1, 5). Procedures for establishing each of the repositories for clonally propagated crops were developed (7). In 1992, each of the repositories prepared site-specific procedures manuals that are maintained at the headquarters offices of the NPGS in Beltsville, MD and at the specific sites.

Activities at the NGR for Apple and Grape in Geneva, NY have been described (2). The collection in Geneva contains 2600 clones of *Malus* along with 500 seed/seedling populations of wild species. Genetic variation of the holdings at the NGR is being studied using morphological, biochemical and molecular techniques (4). The collection is constrained by financial support. The investigations as described (4) and still to be published indicate that many of the 2600 clones are very similar and add little to the diversity of the collection. At least 2100 of the 2600 clones are of the classification *Malus x domestica* (3) which appears to have a very narrow genetic base. There have been at least 35 species of

[1]Horticulturist/Curator, USDA-ARS-NAA, Plant Genetic Resources Unit, Cornell University, Geneva, NY 14456.
[2]Professor Emeritus, Department of Horticultural Sciences, Cornell University, Geneva, NY 14456.