

# Altered Dry Matter Partitioning of 'Starkspur Supreme Delicious' Apple Trees by Nine Rootstocks

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## Abstract

The dry matter partitioning to vegetative and reproductive components of 'Starkspur Supreme Delicious' apple (*Malus domestica* Borkh.) on nine rootstocks in the 1980-81 NC140 Apple Rootstock Trial was determined in March, and again in Oct.-Nov. 1990. Trees on MAC.24 and M.7 EMLA had the heaviest total tree dry weight (DW), while M.26 EMLA was intermediate. Trees on OAR 1, O.3, M.9 EMLA, MAC.9, and M.9 did not differ, and M.27 EMLA had the least total DW. Total tree DW was correlated negatively with percent of fruit, spur, and spur leaf DW and was correlated positively with the percentage of frame, 2-yr and 1-yr wood, current season's growth, and shoot leaf DW.

Apple rootstocks have been shown to influence the partitioning of above-ground dry matter between fruit and vegetative components of the tree (1, 6, 10, 9, 21, 24). Maggs (14) suggested that rootstocks influence tree size by altering the partitioning of dry matter. Evaluations of rootstocks' effects have usually focused on specific growth components such as fruit, spurs, flowers, roots, leaves and shoots, but few have examined the effects on total dry weight and partitioning characteristics of above- and below-ground components of mature apple trees. Forshey et al. (11) reported the standardized dry weights and percent composition for various above-ground growth components of 'McIntosh' apple trees on MM.106, while Westwood and Roberts (25) determined the fresh weight of various scion/rootstock combinations. In 1991, a preliminary summary of the influence of nine rootstocks on the above-ground dry matter partitioning of 'Starkspur Supreme Delicious' apple was reported (23). This paper summarized gross partitioning (vegetative and reproductive) characteristics of the nine rootstocks but lacked information on partitioning of dry weight to specific above-ground components and roots. The influence of fruiting on vegetative growth is well documented. Total canopy leaf area is reduced

with fruiting (Avery, 1969; Hansen, 1971; Maggs, 1963; and Proctor et al., 1976).

The removal of the 1980-81 NC140 apple rootstock trial provided an opportunity for determining the effects of nine apple rootstocks on dry matter partitioning to above-ground and below-ground tree components of a single scion cultivar, 'Starkspur Supreme Delicious.' More specifically, the objectives of this study were to determine: 1) the rootstock effects on partitioning of dry matter to current season's growth, spurs, 1-yr wood, 2-yr wood, frame, spur and shoot leaves, fruit and roots; and 2) evaluate the correlations between the various components and total tree dry weight.

## Materials and Methods

A planting was established as part of the 1980/81 NC-140 Apple Rootstock Trial. The NC140 plot was planted in 1980 and 1981 at the Lewis-Brown Research Farm, located approximately one mile east of Corvallis, Oregon. The performance of the scion cultivar 'Starkspur Supreme Delicious' had been evaluated on the rootstocks O.3, M.7 EMLA, M.9 EMLA, M.26 EMLA, M.27 EMLA, M.9, MAC. 9, MAC. 24, and OAR 1 (16, 17). Five replicates of each rootstock were planted in 1980 and five more in 1981. Trees were

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planted in 10 rows at a spacing of 3.5 x 5.5 m, with each row representing a block of a randomized complete block design. Also, included were two pollinizer rows of 'Macspur' and 'Starkspur Golden Delicious' on M.26 EMLA. Trees were trained to a modified central leader and were pruned uniformly each winter. A 1.5 m herbicide strip was maintained with red fescue between the rows, and irrigation was provided by low head sprinklers. The soil type was a silty clay loam.

In early Mar. 1990, trunk circumference of trees was measured at 25 cm above ground level, and eight replicates of each rootstock were chosen for this study. Based on the reported relationship between total tree fresh weight and trunk cross-sectional area (TCSA) (25), trees within each rootstock were separated into two similar groups of four trees each. For each of the nine rootstocks, one group of four trees was destructively sampled in Mar. 1990, the other in Oct./Nov. 1990. The initial intent for having two sampling times was to estimate the annual growth increment, however, tree variation prevented a meaningful analysis. Yet, the Mar. sampling time did enable an evaluation of the dry weight distribution pattern prior to the growing season.

Above-ground portions of dormant trees were separated into frame, 2-yr wood, 1-yr wood, and spurs, then oven-dried at 60C and weighed in early Mar. 1990. Partitioning of the second group began with fruit harvest in early Oct., where fruit weight per tree was recorded and 50-fruit random subsamples were weighed and placed in cold storage. Remaining above-ground portions were partitioned into frame, 2-yr wood, 1-yr wood, current season's growth, spurs, spur leaves, and shoot leaves, then dried and weighed as before. Fruit subsamples were sliced thin and dried at 30C for 4 days, then completely dried at 60C. Subsample dry weights were used to calculate total fruit dry weight per tree. Roots were excavated with a backhoe by sifting the contents of each bucket of soil taken from a 1.5 m radius around each tree to a 1.5 m depth.

No attempt was made to account for loss due to fruit and leaf drop, or for roots outside the excavation zone. Only a few of the largest trees had roots extending outside the excavation zone, so loss of roots was minimal. Fruit set in 1990 was considered above average, and fruit were not thinned during the growing season.

Data were analyzed by the general linear model (GLM) procedure of Statistical Analysis Systems (SAS) (20). An arcsin/square-root transformation was performed on percent data prior to mean separation by the Waller-Duncan k-ratio t-test, k-ratio = 100. Data in the tables are non-transformed means of the four replicates at each sampling date.

### Results and Discussion

In Mar. 1990, total tree DW's ranged from 56.6 kg for 'Starkspur Supreme Delicious' apple trees on MAC.24 to 2.2 kg for those on M.27 EMLA. Trees on MAC.24 had the highest total tree DW, followed by M.7 EMLA (Table 1). Trees on M.26 EMLA had an intermediate DW, while trees on OAR 1, O.3, M.9 EMLA, and MAC.9 were lower in DW and not significantly different from each other. The total tree DW of trees on M.9 also falls in this group, although DW was significantly less than OAR 1, it was not significantly different than those on O.3, M.9 EMLA, MAC.9, or M.27 EMLA. Trees on M.27 EMLA had the least DW. Dry weights ranged from 56.6 kg for MAC.24 to 2.2 kg for M.27 EMLA.

In Oct./Nov., total tree DW values ranged from 91.5 kg for MAC.24 to 4.2 kg for M.27 EMLA. Trees on MAC.24 were again heaviest, although not significantly heavier than M.7 EMLA. Trees on M.26 EMLA were intermediate, while those on OAR 1, O.3, M.9 EMLA, M.9, and MAC.9 did not differ. Trees on M.27 EMLA had the least total tree DW. Values ranged from 91.5 kg for MAC 24 to 4.2 kg for M.27 EMLA.

Based on total tree DW in Oct./Nov., we grouped these nine rootstocks into four classes. MAC.24 and M.7 EMLA trees were the heaviest, therefore they showed

the greatest growth and could be classified as the most vigorous group in this study. M.26 EMLA falls alone in an intermediate class. OAR 1, O.3, M.9 EMLA, MAC.9, and M.9 make up the dwarf class. M.27 EMLA is alone in the sub-dwarf class. This classification system generally parallels those based on observations of rootstocks with respect to vigor control of the scion (16, 17, 19), although trees on M.7 EMLA and M.26 EMLA were slightly more vigorous than expected. High variability within some rootstocks combined with the small sample size provides a possible explanation. For example, while the mean DW of trees on M.26 EMLA place this rootstock in an intermediate class, individual trees ranged from dwarf to vigorous. Total tree DW of trees on M.9, MAC.24, and M.7 EMLA was also more variable than expected considering they were ge-

netically identical clones. While trees were planted over a 2-year period, there was no correlation between planting date and total tree DW.

Component DW's followed generally the same trends as the total tree DW's. MAC.24 had the greatest DW and M.27 EMLA had the least DW for all components (Table 1). In Oct., fruit DW's ranged from 30.2 kg for trees on MAC.24 to 2.0 kg for trees on M.27 EMLA. Rootstocks fell neatly into the four yield classes, similar to those described earlier for total tree DW.

Percentages of the total DW partitioned to the different components provide another comparison of trees across rootstocks (Table 2). In general, as tree size decreased, a higher percentage of DW was partitioned to fruit, spurs, and spur leaves, while lower percentages went to frame,

**Table 1. Total dry weight partitioned to components to 'Starkspur Supreme Delicious' apple trees on nine rootstocks.<sup>2</sup>**

Rootstock	Dry weight (kg)									
	Frame	2-yr	1-yr	Current	Spur	Root	Shoot leaf	Spur leaf	Fruit	Total
<b>Mar. 1990</b>										
MAC.24	36.4a	2.2a	1.2a		1.0a	15.9a				56.6a
M.7 EMLA	28.1b	1.8b	0.9b		0.9ab	9.4b				41.0b
M.26 EMLA	17.6c	1.2c	0.5c		0.8bc	5.4c				25.5c
OAR 1	7.9d	0.4def	0.1d		0.7bc	6.0c				15.0d
O.3	7.6d	0.7d	0.2d		0.6c	3.5d				12.6de
M.9 EMLA	7.4d	0.5d	0.2d		0.4de	2.4d				10.9de
MAC.9	5.2de	0.4def	0.2d		0.6cd	3.0d				9.2de
M.9	4.7de	0.3ef	0.1d		0.4e	2.7d				8.1ef
M.27 EMLA	1.2e	0.1f	0.01d		0.2f	0.8e				2.2f
<b>Oct./Nov. 1990</b>										
MAC.24	34.9a	3.1a	2.2a	1.3a	1.5a	14.6a	1.8a	2.0ab	30.2a	91.5a
M.7 EMLA	32.1a	2.7a	2.0a	1.3a	1.7a	10.9b	1.8a	2.1a	28.0a	82.6a
M.26 EMLA	18.4b	1.4b	0.7b	0.5b	1.5a	8.4c	0.9b	1.5bc	19.6b	53.0b
OAR 1	7.7c	0.5cd	0.2b	0.04c	0.8b	5.2d	0.07c	1.1cd	0.8c	25.3c
O.3	6.9c	0.7cd	0.5b	0.09c	0.8b	4.8de	0.2c	1.1cd	12.4c	27.3c
M.9 EMLA	7.6c	0.8c	0.3b	0.1c	0.8b	3.3de	0.3c	0.9d	12.3c	26.3c
MAC.9	4.5c	0.3cd	0.08b	0.05c	0.7b	3.4de	0.1c	0.7de	8.2c	17.9cd
M.9	5.4c	0.5cd	0.2b	0.04c	0.7b	2.8ef	0.1c	0.8d	9.3c	19.8c
M.27 EMLA	0.9c	0.05d	0.02b	0.02c	0.3c	0.8f	0.01c	0.2e	2.0d	4.2d

<sup>2</sup>Mean separation in columns and sample date was by the Waller Duncan k-ratio t-test, k-ratio =100. Means are of four replications at each date.

**Table 2. Percentage of dry weight partitioned to components to 'Starkspur Supreme Delicious' apple trees on nine rootstocks.<sup>2</sup>**

Rootstock	Percentage of total dry weight							Shoot leaf	Spur leaf	Fruit
	Frame	2-yr	1-yr	Current	Spur	Root				
<b>Mar. 1990</b>										
MAC.24	64.2ab	3.9abc	2.1a		1.8a	28.0cd				
M.7 EMLA	68.0a	4.2ab	2.2a		2.1de	23.5de				
M.26 EMLA	69.2a	4.9ab	1.7ab		3.1cd	21.1e				
OAR 1	52.1d	2.6c	0.8cd		4.5b	40.0a				
O.3	60.1bc	5.6a	1.8ab		5.1ab	27.4cde				
M.9 EMLA	67.8a	4.7ab	1.9bc		4.0bc	21.6de				
MAC.9	56.2cd	4.0ab	1.5abc		6.5a	31.8bc				
M.9	56.0cd	3.6bc	1.0bcd		4.9b	34.5ab				
M.27 EMLA	54.4cd	3.9abc	0.5d		6.6a	34.6ab				
<b>Oct./Nov. 1990</b>										
MAC.24	37.8a	3.4a	2.4a	1.4a	1.6d	15.9bc	2.1a	2.1e	33.3b	
M.7 EMLA	38.4a	3.3ab	2.3a	1.5a	2.1d	13.6cd	2.1a	2.5de	34.2b	
M.26 EMLA	32.7ab	2.6abc	1.2bc	0.8b	3.2bc	16.6bc	1.6ab	3.0cd	38.3b	
OAR 1	30.5b	1.9cd	0.7cd	0.2d	3.1bc	20.5a	0.3d	4.1ab	38.7b	
O.3	24.9cd	2.4abc	1.6ab	0.3cd	3.0c	17.7ab	0.8c	3.8ab	45.5a	
M.9 EMLA	28.9bc	2.9ab	1.1bc	0.5bc	3.2bc	12.4d	1.0bc	3.3bc	46.7a	
MAC.9	24.8cd	1.3d	0.4b	0.2d	3.7bc	18.9ab	0.6cd	3.8ab	46.3a	
M.9	27.2bc	2.3bc	0.8cd	0.2d	3.9b	13.5cd	0.5cd	3.9ab	47.7a	
M.27 EMLA	21.9d	1.2d	0.4d	0.4cd	5.9a	18.4ab	0.2d	4.3a	47.3a	

<sup>2</sup>Mean separation in columns and sample date was by the Waller Duncan k-ratio t-test, k-ratio=100. Means are of four replications at each date.

2-yr wood, 1-yr wood, current season's growth, and shoot leaves. Based on the percentage of DW partitioned to fruit, two groups of rootstocks were apparent. Trees on M.9, M.27 EMLA, M.9 EMLA, MAC.9, and O.3 partitioned the most DW to fruit, with values ranging from 47.7% for M.9 trees to 45.5% for O.3 trees. Trees on OAR 1, M.26 EMLA, M.7 EMLA, and MAC.24 partitioned significantly less DW to fruit ranging from 33.3 to 38.7%. Spur leaf DW percentages ranged from 4.3 for trees on M.27 EMLA to 2.1 for those on MAC.24. Percentages of spur DW ranged from 5.9 for trees on M.27 EMLA to 1.6 for those on MAC.24. The percentage of current season's growth DW was greater for the most vigorous rootstocks, MAC.24 and M.7 EMLA. The lowest percentage of current season's growth DW was observed for OAR 1,

MAC.9, M.9, O.3 and M.9 EMLA trees. Trees on M.26 EMLA were intermediate for the partitioning of the vegetative component. A similar pattern was observed for the percentage of shoot leaf DW. Working with larger trees (McIntosh/ MM.106) in a below average crop year, Forshey et al. (11) found much lower percentages partitioned to fruit (18.3%) and spurs (0.6%) than any of the trees in this study, while wood components (70.5%) were much higher. 'Starkspur Supreme Delicious' is a spur-type tree while 'McIntosh' is not. The growth habits of the two cultivars could explain some of these differences.

In general, as the vigor of the rootstock increased, the percent spur and spur leaf DW decreased and the percentage of current season's growth and shoot leaf DW increased. It is interesting to note that OAR1 trees, which fell into the grouping

of trees with a lower partitioning to fruit, had a high percentage of spur and spur leaf DW and a small percentage of current season's growth and shoot leaf DW. Based on these vegetative distribution patterns, one might expect OAR1 to partition more DW to fruit and be more productive. In summaries of this NC140 trial, OAR1 has had a low yield efficiency and small fruit size (16, 17). From the data in this study, we can deduce that fruit set of this more "spurry" tree is less than others with similar spur DW and spur leaf DW partitioning characteristics.

Cropping has been shown to reduce shoot growth (3, 4, 7, 8, 15). Those rootstocks that partitioned proportionately more DW to fruit also partitioned proportionately less to shoot leaves and more to spur leaves. Trees on M.7 EMLA, MAC.24, and M.26 EMLA partitioned 3.4, 3.0 and 2.8 percent of its non-reproductive components to shoot leaves and only 3.8, 3.2 and 4.5 percent to the spur leaves, respectively. In contrast, M.9 EMLA, O.3, MAC.9 and M.9 partitioned 1.9, 1.5, 1.2 and 1.0 percent to the shoot leaves and 6.2, 7.0, 6.9 and 7.2 percent to the spur leaves, respectively. The percentage of shoot leaf DW from the vegetative components for trees on OAR.1 and M.27 EMLA was very low, 0.4 and 0.5 percent, respectively. While, 6.8 and 8.3 percent of the total vegetative components' DW were allocated to spurs for trees on OAR.1 and M.27 EMLA, respectively. Schechter et al (21) had similar observations when shoot leaf DW was adjusted for limb circumference. Both these rootstocks have had diffi-

culty sizing fruit (16, 17). Since, shoot leaves have been shown to contribute to fruit growth (12, 13), the limited shoot growth by trees on this rootstock could explain this difficulty.

The ratio of shoot leaf DW to current season's growth DW was approximately 1.5 or greater and the spur DW to spur leaf DW ratio was about 1.0, with one exception, M.27 EMLA trees. The ratios were only 0.5 and 0.7 for shoot and spur ratios, respectively. These reduced ratios, suggesting smaller or fewer leaves per current season's growth and spurs may also contribute to the 'runting out' phenomenon and small fruit size from trees on M.27 EMLA.

Correlations between the percentage of DW partitioned to different components and the total DW reveal the relationship between fruiting and vegetative growth (Table 3). There were highly significant negative correlations between total DW and percent fruit DW ( $r = -0.77$ ), percent spur DW ( $r = -0.78$ ), and percent spur leaf ( $r = -0.76$ ) DWs. Highly significant positive correlations ( $P = 0.01$ ) were found between total DW and the percentage DW of frame ( $r = +0.86$ ), 2-yr wood DW ( $r = +0.61$ ), 1-yr wood DW ( $r = +0.79$ ), current season's growth DW ( $r = +0.88$ ), and shoot leaf DW ( $r = +0.85$ ). As tree size increased, the percentage of total DW partitioned to roots decreased. There was a significant ( $P < 0.05$ ) negative correlation between percentages of root DW and frame DW ( $r = -0.34$ ), 2-yr wood DW ( $r = -0.51$ ), 1-yr wood DW ( $r = -0.37$ ), current season's growth DW ( $r = -0.36$ ), and shoot

**Table 3. Correlations between the percentages of dry weight (DW) partitioned to components and total dry weight of 'Starkspur Supreme Delicious' apple trees in Oct. 1990.**

	Correlation coefficients between percentages of DW								Total DW
	2-yr	1-yr	Current	Spur	Root	Shoot leaf	Spur leaf	Fruit	
Frame	0.58**	0.61**	0.73**	-0.64**	-0.34*	0.78**	-0.059**	-0.90**	0.86**
Spur	-0.66**	-0.72**	-0.62**		0.29ns	-0.65**	0.70**	0.50**	-0.78**
Root	-0.51**	-0.37*	-0.36*			-0.42*	0.41*	-0.07ns	-0.32*
Fruit	-0.44**	-0.57**	-0.68**			-0.70**	0.43**		-0.77**
Total DW	0.61**	0.79**	0.88**			0.85**	-0.76**		

\*\* , \* , ns; significant at  $p = 0.01$ ,  $p = 0.05$ , or nonsignificant, respectively.

leaf DW ( $r = -0.42$ ). The percentage of root DW was positively correlated ( $r = 0.41$ ,  $P < 0.05$ ) with spur leaf DW.

The negative correlation ( $P = 0.051$ ) between the percentage root and total DW ( $r = -0.32$ ) suggests that heavier trees are producing more above-ground DW per root DW. The above-ground to root DW ratios (Table 4), however, explain why the correlations are relatively weak compared to the correlations between fruiting and growth components. Trees on M.9 EMLA, M.9 and M.7 EMLA had the highest ratios, followed by MAC.24, M.26 EMLA, O.3, M.27 EMLA, MAC.9, and OAR 1. Although the heavier trees MAC.24, M.7 EMLA, and M.26 EMLA had a high ratio, they were not the highest. It is clear that mass of roots is not the sole determiner of total tree size.

While the mechanisms of dwarfing are not fully understood, rootstocks affect the total tree DW and alter the partitioning characteristics of a scion cultivar. As total tree DW decreased, the percentage partitioned to fruit increased. Competition for available photosynthate has been suggested as a possible dwarfing mechanism since a higher percentage of photosynthate partitioned to fruit means less available for vegetative growth (5). However, this explanation does not account for differences in rootstock response observed

prior to the onset of fruiting (1, 2) and in years of total crop loss (18, 21). Additionally, as tree size increased, the percentage of total DW partitioned to roots tended to decrease. Perhaps a mechanism exists within the more size-controlling rootstocks whereby the rootstock reduces the mobilization of root reserves to the above-ground portion of the tree, resulting in less vegetative growth. Additionally, the shift in ability of some rootstocks to partition more dry weight to spurs and spur leaves and less to current season's growth and shoot leaves also suggests a possible mechanism for increasing yield potential. It is likely that differences in rootstock physiology produce the observed responses, and cropping can attenuate vegetative growth within a range genetically predetermined by the rootstock.

### Literature Cited

1. Avery, D. J. 1969. Comparisons of fruiting and deblossomed maiden apple trees, and of non-fruiting trees on a dwarfing and an invigorating rootstock. *New Phytol.* 68:323-336.
2. Avery, D. J. 1970. Effects of fruiting on the growth of apple trees on four rootstock varieties. *New Phytol.* 69:19-30.
3. Avery, D. J. 1975. Reduction in growth increments by crop competition, p. 103-105. In: H. D. Pereira (ed.s). *Climate and the orchard.* Cmwth. Agr. Bur., Slough, U.K.
4. Barlow, H. W. B. 1975. Effects of cropping on the growth of orchard trees, p. 98-102. In: H. C. Pereira (ed.). *Climate in the orchard.* Cmwth. Agr. Bur., Slough, U.K.
5. Beakbane, A. B. 1956. Possible mechanisms of rootstock effect. *Ann. Appl. Biol.* 44:517-521.
6. Collison, R. C. and J. D. Harlan. 1930. Variability and size relations in apple trees. *N.Y. Ag. Exp. Sta. Tech. Bull.* 164, pp. 3-38.
7. Forshey, C. G. 1982. Effects of fruiting, pruning, and nitrogen fertilization on shoot growth of 'Empire' apple trees. *J. Amer. Soc. Hort. Sci.* 107:1092-1097.
8. Forshey, C. G. and C. A. Marmo. 1985. Pruning and deblossoming effects on shoot growth and leaf area of 'McIntosh' apple trees. *J. Amer. Soc. Hort. Sci.* 110:128-132.
9. Forshey, C. G. and D. C. Elfving. 1989. The relationship between vegetative growth and fruiting in apple trees. *Hort. Rev.* 11:229-287.
10. Forshey, C. G. and M. W. McKee. 1970. Production efficiency of a large and small 'McIntosh' apple tree. *HortScience* 5:164-165.

**Table 4. Ratio of above-ground to root DW for 'Starkspur Supreme Delicious' apple trees on nine rootstocks in Mar. and Oct./Nov.**

Rootstock	Ratio of above-ground to root DW	
	Mar. 1990	Oct./Nov 1990
MAC.24	2.6bc	5.3bc
M.7 EMLA	3.4ab	6.5ab
M.26 EMLA	3.8a	5.2c
OAR 1	1.5d	3.9d
O.3	2.8bc	4.7cd
M.9 EMLA	3.7a	7.1a
MAC.9	2.2cd	4.3cd
M.9	2.0cd	6.5ab
M.27 EMLA	2.0cd	4.6cd

<sup>2</sup>Means separation in columns by Waller Duncan k-ratio t-test, k-ratio=100. Means are of four replications at each date.

- Forshey, C. G., R. W. Weires, B. H. Stanley, and R. C. Sem. 1983. Dry weight partitioning of 'McIntosh' apple trees. J. Amer. Soc. Hort. Sci. 108:149-154.
- Hansen, P. 1967b. <sup>14</sup>C-studies on apple trees. II. Distribution of photosynthates from top and base leaves from extension shoots. Physiol. Plant. 20:720-725.
- Hansen, P. 1969. <sup>14</sup>C-studies on apple trees. IV. Photosynthate consumption on fruits in relation to the leaf-fruit ratio and to the leaf-fruit position. Physiol. Plant. 22:186-198.
- Maggs, D. H. 1958. A comparison of the growth patterns of two apple rootstock varieties during their first year. Annu. Rpt. E. Malling Res. Sta. 1957. p. 101-105.
- Maggs, D. H. 1963. The reduction in growth of apple trees brought about by fruiting. J. Hort. Sci. 38:119-128.
- NC-140. 1987. Growth and production of 'Starkspur Supreme Delicious' on 9 rootstocks in the NC-140 Cooperative Planting. Fruit Var. J. 41:31-39.
- NC-140. 1991. Performance of 'Starkspur Supreme Delicious' apple on 9 rootstocks over 10 years in the NC-140 Cooperative Planting. Fruit Var. J. 45:192-199.
- Rogers, W. S. and G. A. Booth. 1964. Relationship of crop and shoot growth in apples. J. Hort. Sci. 39:61-65.
- Rom, R. C. and R. F. Carlson. 1987. Rootstocks for fruit crops. John Wiley and Sons, New York, N.Y.
- SAS Institute, Inc. 1985. SAS User's Guide: Statistics, version 5 edition. Cdry., N.C.
- Schechter, I., D. C. Elfving, and J. T. A. Proctor. 1991. Rootstock affects vegetative growth characteristics and productivity of 'Delicious' apple. HortScience 26:1145-1148.
- Singh, L. B. 1948. Studies in biennial bearing. III. Growth studies in "on" and "off" years. J. Hort. Sci. 24:123-148.
- Strong, D. and A. Miller-Azarenko. 1991. Dry matter partitioning in 'Starkspur Supreme Delicious' on nine rootstock. Fruit Var. J. 45:238-241.
- Vyvyan, M. D. 1934. The distribution of growth between roots, stems, and leaves in a young apple tree and its possible bearing on the problem of stock effect on tree vigour. Ann. Rep. E. Malling Res. Sta. 1933:122-131.
- Westwood, M. N. and A. N. Roberts. 1970. The relationship between trunk cross-sectional area and weight of apple trees. J. Amer. Soc. Hort. Sci. 95:28-30.

GROWING WITH YOU...™							
APPLE							
	M-9	M-9 (NC 19)	BUD-9	M-9/EMLA 111	EMLA 26	EMLA 7	EMLA106
							EMLA111
							CC-16
							SDIG.
ALES SPUR DELICIOUS PP#4587							
ACE77 MAC							
AUTUMN GOLDS (HEIN CV.) PP#9007							
SUPR CHIEF 8 SPUR RED DELICIOUS (SANDIDGE CV.) PP#6190							
BRAEBURN							
CANOP™ (CAUDLE CV.) PP#9068							
CHINOOK							
CORTLAND							
CORTLAND ROYAL COURT™ (HARTENCOURT CV.) PP#10049							
EMPIRE CROWN™ (CRIST CV. CB1515) PPAF							
EMPIRE™ ROYAL CREPLE CV.) PP#7820							
FORTUNA NY 429 PPAF							
FUJI, RED SPORT #2							
FUJI, SUN FUJI™							
GALA GRIMSON® GALA (WALISER CV.) PP#673							
GALA, FULFORD GALA® PP#7589							
GALA™, GALE (MALAGA CV.) PP#10114							
GALA (MITCHELL CV.)							
GINGER GOLDS (MTN. COVE CV.) PP#7063							
GOLDEN DELICIOUS (GIBSON STRAIN)							
GRANNY SMITH							
GRINES GOLDEN							
HONEYCRISP® (MINN. 17118 CV.) PP#7197							
INABED							
JERSEYRED							
JONAGOLD DE COSTER™ PP#8049							
JONAMAC							
JONATHAN, IMPROVED RED (SNYDER STRAIN)							
LADY							
LODI							
MAGNOL							
McINTOSH, MARSHALL®							
McINTOSH, PRONER® MAC (GREINER STRAIN) PP#7002							
McINTOSH, ROGERS RED McINTOSH							
McINTOSH, SCOTTAN SPUR MAC PP#10770							
MELROSE							
MITSU/CRISPIN							

APPLE										
	M-9	M-9 (NC 19)	BUD-9	M-9/EMLA 111	EMLA 26	EMLA 7	EMLA106	EMLA111	CC-16	SDIG.
NITTANY										
NORTHERN SPY										
N. W. GREENING										
PINK LADY 8 (CRIPPS PINK CV.) PP#7880										
ROME, RED ROME BEAUTY (LAW STRAIN)										
RED ROME 262										
ROME, SP. R. ROME (TAYLOR STRAIN)										
SANSA PP#6919										
SHIZUKA										
SMOKEHOUSE										
STAYMAN, SNAPP STAYMAN™ (AS510) PP#11071										
SUMMER MAC (AREBUS STRAIN)										
SUMMER RAMBL®										
SUNCRISP® (N) 55 CV.) PP#9648										
SUNRISE® (DAPINS CV.)										
VIRGINIA GOLD										
WINESAP, RED WINESAP										
YATKAM PP#7001										
YELLOW TRANSPARENT										
YORK, RAMEY YORK										
YORK, RED YORKING										


APPLE - Disease Resistant Varieties										
ENTERPRISE™ (COOP. 30 CV.) PP#9193										
FREEDOM PP#523										
GOLDRUSH® (COOP. 38 CV.) PP#9932										
LIBERTY										
PRISTINE® (COOP. 32 CV.) PP#9881										
REDFREE PP#4322										

APPLE - Pollinizers										
MANCHURIAN										
SNOWDRIFT										
SPUR WINTER BANANA										
JONAMAC										

\* LIMITED AVAILABILITY

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