Rootstock Affects Primary Scaffold Branch Crotch Angle of Apple Trees

John Warner

Agriculture Canada, Research Station, P. O. Box 340, Trenton, Ont. K8V 5R5, Canada

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Abstract. 'Sturdeespur Delicious', 'MacSpur', 'Summerland McIntosh', 'Idared', and 'Empire' apple trees (*Malus domestics* Borkh.) planted in 1986 on various size-controlling rootstock were used to determine the effect of rootstock on primary scaffold branch crotch angle. There were differences in crotch angle depending on rootstock. Rootstock effects were more pronounced with the upright growing 'Sturdeespur Delicious' than with 'Idared' and 'Empire', which have a spreading growth habit. Ottawa 8 rootstock had a tendency to produce primary branches with wider crotch angles than other semidwarf to standard rootstock.

Scaffold branches with wide crotch angles are important in training trees to central leader systems. Wide crotch angles form strong unions between branches and adjacent tissues of the trunk and will carry heavy crop loads without breakage (Teskey and Shoemaker, 1972). In contrast, narrow crotch angles form weaker unions due to bark inclusion between the branch and trunk. Tissues in narrow crotches are slower to develop hardness in the autumn and may be damaged by low winter temperatures (Fisher, 1990). Narrow crotches may also offer points of entry for boring insects or disease organisms.

Apple cultivars differ in primary branch angles. Spur-type strains have more upright growth habits than nonspur strains, differences primarily under genetic control (Quinlan and Tobutt, 1990). Cultural practices also affect branch angles. The crotch angles of primary branches were wider where feathers (1-year-old lateral branches) were used compared with branches formed on trees that were headed and all feathers removed (Preston, 1968). Heading, to remove part of the current-season's growth, or leaf removal (leaving the growing tip intact) may affect the number of branches produced and branch angles (Olien, 1987; Wertheim, 1978). Lower branches usually have greater angles than upper branches (Preston, 1968). The interaction of endogenous growth regulators, primarily auxins and cytokinins, is thought to play a major role in the control of lateral bud development (Sachs and Thimann, 1967). There have been numerous reports of growth-

regulating chemicals affecting branch crotch angles (Elfving and Forshey, 1977; Verner, 1938; Williams and Billingsley, 1970). This report provides evidence of rootstock influence on crotch angle development of primary branches.

Semidwarf or vigorous rootstock (Expt. 1). Two-year-old branched trees of 'Empire' and 'Idared' and 1-year-old whips (unbranched) of 'Sturdeespur Delicious', 'MacSpur', and 'Summerland McIntosh' on MM.106, MM.111, MAC.1, Ottawa (Ott.) 8 and Beautiful Arcade seedling (BA) rootstock were planted in Spring 1986 at a 5 × 6 m spacing. After the 2-year-old trees were planted, branches below the 46-cm height were removed and three to five primary branches were selected; all others were removed. The leader was headed ≈ 30 cm above the uppermost branch, and all of the primary branches were headed by removing about one-third of the new growth. Whips were headed at 80 cm above ground level. In subsequent years, the leader was headed annually by removing one-third of the previous season's growth. Four to six lower scaffold limbs were selected, removing branches that were competing with the leader, below 46 cm in height, or were poorly positioned. Dormant thinning cuts were also made to remove lateral shoots on the primary branches that were competing with primary branch terminal shoots. No limb spreading was done. Trees were defruited during the first 3 years and allowed to crop in years 4 and 5 (1989 and 1990).

Dwarfing rootstock (Expt. 2). One-year-old 'Empire', 'Idared', 'Summerland McIntosh', and 'Macspur' whips on a series of dwarfing rootstock were set at 2.5 × 4 m. Each tree was supported by a 2.4-m cedar post. Trees were trained as described in Expt. 1 for whips.

In both experiments, a split plot, incomplete-block design was used. Cultivars were replicated within each main plot and rootstock were replicated within each subplot.

One to three trees on a given rootstock made up each subplot. There were five replications in Expt. 1 and four replications in Expt. 2.

In 1990, scaffold branch crotch angles of the four lowest branches on each tree were measured using a 150-cm-diameter protractor. Mean crotch angle was determined for each tree. Tree trunk girth at 36 cm above the bud union was measured in the autumn and converted to trunk cross-sectional area.

Data for each experiment were analyzed using the General Linear Models procedure (SAS Institute Inc., 1985). Mean separation was performed using the least-squares means procedure. In Expt. 2, each cultivar was analyzed separately since there was a different number of rootstocks for each cultivar. When the data for Expt. 1 were analyzed, the cultivar × rootstock effects were significant ($P = 0.05$), therefore, data for each cultivar are shown separately.

Except for 'Empire' and 'Idared' in Expt. 1, the crotch angles measured in these experiments were formed by primary branches produced in the orchard, and influenced by heading cuts made after planting. With 'Empire' and 'Idared' in Expt. 1, crotch angles formed in the nursery were also influenced by dormant heading cuts made in the nursery 1 year earlier (Preston, 1968). Olien (1987) reported that average branch angle of 'Cortland' trees decreased linearly with a decrease in heading height, but 'Macspur', 'Golden Delicious', and 'Redchief Delicious' were not affected by heading height. Since trees were defruited in years 1 to 3, cropping did not affect crotch angle formation. Cropping in years 4 and 5 may have affected branch angle (some distance from the crotch), but crotch angles close to the trunk were already formed.

In the experiments reported here, rootstock affected mean crotch angle but influenced cultivars differently. In Expt. 1, 'Sturdeespur Delicious' on MM.106, MM. 111, and Ott.8 rootstock had wider crotch angles than on BA or MAC. 1 (Table 1). With 'MacSpur', 'Summerland McIntosh', and 'Empire', rootstock also influenced crotch angle. 'Macspur'/Ott.8 had a wider crotch angle than 'Macspur'/MM. 106, and 'Summerland McIntosh'/Ott.8 had a wider crotch angle than 'Summerland McIntosh'/BA. With 'Empire', Ott.8 had a wider crotch angle than MM.106, MM.111, and MAC.1. With 'Idared', no significant difference ($P = 0.05$) in mean crotch angle occurred between the five rootstock.

In Expt. 2, 'Summerland McIntosh'/M.26 had a narrower mean crotch angle than B.9, CG.10, P.22, Ott. 3, and MAC.9 (Table 2). With 'Idared', B.57-146 had a narrower crotch angle than did trees on M.26 or Ott.3. 'MacSpur' trees on P.22 had wider crotch angles than did trees on B.57-146 or M.26. No significant differences ($P = 0.05$) in mean crotch angle occurred among rootstock with

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Table 1. Mean scaffold branch crotch angle and trunk area (Oct. 1990) of five apple cultivars on semidwarf to vigorous rootstocks.²

Rootstock	Sturdeespur Delicious			MacSpur			Summerland McIntosh			Idared			Empire		
	N ³	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)
BA*	15	56 a	39 a	15	68 ab	45 a	5	66 a	39 a	15	70	39 a	11	76 ab	42 ab
MAC.1	8	57 a	36 a	11	68 ab	45 a				14	71	39 a	11	72 a	44 a
MM.111	15	63 b	22 b	11	68 ab	34 b	15	69 ab	28 bc	15	73	29 b	15	71 a	31 b
MM.106	14	66 b	26 b	15	65 a	30 b	10	72 ab	26 c	15	68	27 b	14	71 a	30 b
Ott.8	10	68 b	26 b	8	74 b	31 b	10	73 b	33 ab	15	74	30 b	12	79 b	28 b
Mean of rootstocks	62	62	30	60	68	37	40	70	30	74	71	33	63	74	34

²Means separation within columns by least square means, $P = 0.05$. Absence of letters indicates no significant difference.

³N = No. trees measured, four branch angles per tree, May 1990. Trees 4 years old.

*BA = Beautiful Arcade.

Table 2. Mean scaffold branch crotch angle and trunk area (Oct. 1990) of four cultivars on dwarfing rootstocks.²

Rootstock	Summerland McIntosh			Idared			MacSpur			Empire		
	N ³	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)	N	Mean crotch angle	Trunk area (cm ²)
M.26	8	64 a	21 a	8	76 b	18 a	8	73 a	14 a	8	78	15 ab
Ott.3	4	72 bc	15 ab	8	74 b	17 a				8	80	15 a
MAC.9	8	75 c	14 b							8	79	12 bc
CG.10	8	72 bc	10 cd							4	79	8 cd
B.9	8	72 bc	10 c							8	81	8 d
M.27	8	69 ab	7 de							8	79	7 d
P.22	6	72 bc	5 e				8	78 b	6 b	4	78	7 d
B.57-146				4	67 a	4 b	8	73 a	5 b	6	80	5 d
Mean of rootstocks	50	71	12	20	74	15	24	75	8	54	79	10

²Means separation within columns by least square means, $P = 0.05$. Absence of letters indicates no significant difference.

³N = No. trees measured, four branch angles per tree, June 1990. Trees 4 years old.

'Empire' as the scion cultivar. The rootstock effects on crotch angle were more pronounced on the upright-growing 'Delicious' than on 'Idared' and 'Empire', which have a more spreading growth habit.

Rootstock vigor may be one factor affecting crotch angle. With 'Sturdeespur Delicious', trunk cross-sectional area was negatively correlated to crotch angle ($P = 0.003$, $r = -0.38$). However, this relationship was not significant ($P = 0.05$) for other cultivars.

When training apple trees, both crotch angle (where the branch joins the central leader) and branch angle (some distance from the crotch) are important. Wider crotch angles are not necessarily reflected in wider branch angles; nevertheless, wide crotch angles are important in forming strong unions between the limb and the trunk. Pomologists may be

able to select rootstock as well as cultivars that favor the production of wide crotch angles.

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