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Survival and Growth of 'Empire' Apple Trees Chip Budded onto Mark or M.9 Rootstock

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Abstract

'Empire' apple (*Malus domestica* Borkh.) was budded onto Mark or M.9 rootstock on 16 July, 9 Aug., 30 Aug., or 23 Sept. 1990 in Illinois and Washington to determine the effect of time of chip budding on tree survival, scion growth, and union overgrowth. Most of the trees (≥ 68%) propagated in July or August produced scion growth by 5 May 1991. However, scion wilting occurred subsequently, resulting in substantial tree loss. By October 1991, scions that were budded on Mark rootstock on 30 Aug. 1990 generally had the greatest survival at both locations. In contrast, 'Empire'/M.9 trees chip budded in Illinois on 23 Sept. tended to have the greatest scion survival and growth and number of branches. In Washington, M.9 rootstocks budded on 16 July had greater scion survival than those budded on 30 Aug. or 23 Sept.

Introduction

Apple trees are commonly propagated by T-budding or chip budding a scion cultivar onto a clonal rootstock in the field (2, 4). Although T-budding can be accomplished quickly with a relatively high percentage of bud-take, *Nectria galligena* Bres. spores on the scionwood can readily infect the rootstock when the bud shield is inserted under the bark of the rootstock and produce union cankers (5). In contrast, a small portion of the rootstock tissue is removed and replaced with scionwood in chip budding, resulting in a low incidence of union cankers (3). Another disadvantage of T-budding is that it is restricted to late summer when the bark "slips" (i.e. the phloem and cambium separates readily from the xylem) (2).

Union formation in chip budded trees occurs soon after budding because the cambium of the rootstock and scion are placed in direct contact. Early union formation in chip budded trees resulted in higher bud-take, stronger unions, and a greater number and length of lateral branches than apple trees that were T-budded (3). Additionally, chip-budding may be successfully accomplished from early spring to late summer (6).

Although the time for chip budding is less restrictive than that of T-budding, there is an optimal chip budding period when a high percentage of bud-take is achieved (3). For example, 79% of the 'Jonagold'/Mark trees chip budded on 31 Aug. in Washington formed a compatible union and produced normal scion growth, whereas just 25% of the trees budded on 21 Sept. grew the following spring (8). In the same study, a high percentage of 'Jonagold'/Mark trees budded in Illinois on 31 Aug. also established a union in the fall, but a vascular aberration in the scion resulted in wilted new growth in the spring.

Since nurserymen have had difficulty in propagating trees on Mark rootstock (8), the objective of this study was to determine if the time of chip budding affected the growth and survival of 'Empire' buds on Mark and M.9 rootstocks. Preliminary results from an earlier study indicated that climatic conditions affected callus growth and union formation. Thus, research plots were located at two nursery sites, in Illinois and Washington. M.9 was included in the study as a standard for comparison since Mark was derived from open pollinated M.9 seed (1).

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Materials and Methods

'Empire' budwood was collected from a virus-free scionwood orchard in Louisiana, Missouri on 13 July, 6 Aug., 27 Aug., and 20 Sept. 1990 and shipped by overnight mail to Wenatchee, Washington or stored at 2°C for use in the Illinois nursery. The rootstock plantings used in this study were located at commercial nursery sites in Atlas, Illinois and George, Washington.

Scion buds from each collection date were chip budded onto Mark and M.9 NAKB T337 rootstocks at each location three days after budwood collection. In Illinois, the initial size of the rootstock liners were 4-6 mm-diameter when planted in spring 1990. The diameter of rootstock liners was not measured at planting in Washington.

Four, 15-tree replicates of each rootstock at each budding date were arranged in a randomized complete block design in Illinois. In Washington, two separate rootstock plantings were utilized with four, 15-tree replicates of each budding date arranged in a randomized complete block design. Scion survival and length of the new growth were recorded on 5 May, 1991. On 9 Oct., scion growth and survival, leader diameter (measured 7.6 cm above the union), number of branches > 10 cm long, and the union and rootstock diameter (measured 2.5 cm below the union) were recorded. Union overgrowth, the ratio of the union diameter to the rootstock diameter, was also calculated. All data from Illinois, except that recorded for scion wilting, were analyzed as a two-way factorial arrangement of treatments in which the linear statistical model contained the main effects of rootstocks and budding date, and interactions among these main effects. Scion wilting data were analyzed as a one-way analysis of variance since only six (of a total of 60) scions budded on Mark rootstock on 23 Sept. had grown from the bud on 28 May. Separate analyses of variance were performed on data collected from each rootstock planting in Washington. Treatment means were separated by a least significant (LSD) test.

Results

Trees budded in the fall were not exposed to temperatures below 0°C for at least 24 days after budding. The first autumn frost occurred on 17 and 22 Oct. 1990 in Washington and Illinois, respectively. Temperatures were generally cooler in Washington than in Illinois, with 5 frosts recorded in October. A second frost did not occur in Illinois until 28 Nov. Thus, callus growth at the union did not appear to be inhibited by low temperatures in the fall.

Table 1. The percentage of trees that exhibited scion growth and scion length in Illinois and Washington on 5 May 1991.

Rootstock	Budding date (1990)	Trees with scion growth (%)[z]	Scion length (cm)[y]
	Illinois		
Mark	16 July	92	13.7
	9 Aug.	88	15.3
	30 Aug.	83	15.4
	23 Sept.	8	1.1
M.9	16 July	93	9.1
	9 Aug.	87	9.2
	30 Aug.	95	12.6
	23 Sept.	68	11.9
LSD 0.05 =		26	4.6
	Washington		
Mark	16 July	95	3.6
	9 Aug.	100	4.6
	30 Aug.	95	5.5
	23 Sept.	8	0.2
LSD 0.05 =		9	1.2
M.9	16 July	98	4.0
	9 Aug.	92	4.1
	30 Aug.	68	3.4
	23 Sept.	10	0.5
LSD 0.05 =		21	1.6

[z]Analysis performed on arcsin $\sqrt{x}$ transformed data.
[y]Length of the leader measured from the bud union.

In Illinois, rootstocks began to grow early in the spring. Before removal on 3 Apr. 1991, rootstock suckers on M.9 trees averaged ≈ 15 cm long, whereas those on Mark were ≈ 3 cm long. Bud scales on the scions had begun to separate at this time. By early May, fewer Mark trees budded on 23 Sept. in Illinois produced scion growth than those budded on all other dates (Table 1). Mark trees budded on 23 Sept. also had shorter scions than all other trees. A higher percentage of M.9 trees budded on 30 Aug. in Illinois had scion growth than M.9 trees budded on 23. Sept. Scion length of M.9 trees was similar among all budding dates in May.

In Washington, fewer trees budded in September on both rootstocks had produced scion growth in May than those budded on all other dates. M.9 trees budded on 30 Aug. also had a lower percentage of scion growth than M.9 trees budded on 16 July or 9 Aug. Mark trees budded on 30 Aug. had longer scions than those budded on 16 July or 23 Sept. Scions of M.9 trees budded in September were shorter than those of M.9 trees budded at earlier dates.

By 28 May 1991, scion wilting was observed at both locations. In Illinois, trees budded on Mark rootstock on 9 Aug. had a greater percentage of scion wilting than those budded at all other dates, except Mark trees budded on 16 July (Table 2). The percentage of scion wilting of Mark trees budded on 30 Aug. was similar to that of M.9 trees at each budding date. Scion wilting of Mark trees budded on 23 Sept. could not be compared with other treatments since only 6 of the 60 Mark rootstocks budded in September had produced growth from the scion bud by 28 May 1991.

In Washington, the percentage of trees that exhibited scion wilting was recorded on 3 June 1991 (Table 2). Scion wilting was not observed on any trees budded on the last two budding dates. However, 29% of the Mark trees budded on 9 Aug. had wilted scion growth, whereas ≤ 7% of the M.9 trees budded on 9 Aug. and Mark and M.9 trees budded on 16 July exhibited scion wilting. In an earlier study with 'Empire' and 'Jonagold' budded on Mark rootstock, scion wilting occurred in Washington on approximately 30% of the trees budded on 10 Aug., while ≤ 3 of the trees budded on 31 Aug. or 21 Sept. had wilted scion growth (Warmund and Barritt, unpublished data).

From 5 to 28 May 1991 in Illinois, the average maximum daily temperature was 26°C, with the temperature exceeding 31°C on four days. In Washington, the average maximum daily temperature was 22°C, with the temperature reaching 27°C on three days. Thus, high temperatures during May may have contributed to extensive scion wilting and loss in Illinois.

Table 2. The percentage of trees that exhibited scion wilting on 28 May in Illinois and on 3 June in Washington.

Rootstock	Budding date	Scion wilting (%)[z]
	Illinois	
Mark	16 July	79
	9 Aug.	84
	30 Aug.	51
	23 Sept.	--[y]
M.9	16 July	48
	9 Aug.	50
	30 Aug.	55
	23 Sept.	33
LSD 0.05 =		27
	Washington	
Mark	16 July	5
	9 Aug.	29
	30 Aug.	0
	23 Sept.	0
M.9	16 July	2
	9 Aug.	7
	30 Aug.	0
	23 Sept.	0

[z]Analysis performed on arcsin $\sqrt{x}$ transformed data.
[y]No wilting occurred at this date. Only 6 of 60 trees budded on this date had any scion growth.

Table 3. Scion survival and growth parameters of 'Empire' scions on Mark and M.9 rootstock in Illinois and Washington on 9 Oct. 1991.

Rootstock	Budding date	% Scion survival	Leader diameter (mm)[z]	Leader length (cm)[y]	Total scion growth (cm)[x]	Branch no.	Union overgrowth[w]
			Illinois				
Mark	16 July	22	13.3	139	222	2.5	1.47
	9 Aug.	12	12.9	154	263	3.7	1.34
	30 Aug.	37	13.9	146	286	4.0	1.38
	23 Sept.	15	13.7	136	216	2.9	1.41
M.9	16 July	40	12.9	123	249	3.2	1.23
	9 Aug.	27	13.0	124	292	4.2	1.21
	30 Aug.	38	13.8	122	301	4.6	1.19
	23 Sept.	53	16.3	141	390	5.7	1.14
LSD 0.05 =		17	NS	17	93	1.8	0.08
			Washington				
Mark	16 July	63	17.9	157	294	2.5	1.57
	9 Aug.	52	17.4	153	303	3.0	1.56
	30 Aug.	73	18.5	166	337	3.5	1.55
	23 Sept.	13	21.0	171	399	3.9	1.42
LSD 0.05 =		29	1.3	NS	NS	NS	0.07
M.9	16 July	92	12.4	122	122	0	1.22
	9 Aug.	83	12.8	124	124	0	1.22
	30 Aug.	67	12.8	123	123	0	1.27
	23 Sept.	17	14.5	126	126	0	1.21
LSD 0.05 =		23	NS	NS	NS	NS	NS

[z]Diameter measured at 7.6 cm above the union.
[y]Leader length measured from the union.
[x]Length of leader + length of all lateral branches.
[w]Ration of union diameter to rootstock diameter.

By October 1991, scion survival was ≤ 53% in Illinois (Table 3). Scions of M.9 trees budded on 23 Sept. had greater survival than scions of M.9 trees budded on 9 Aug. or Mark trees budded on 16 July, 9 Aug. or 23 Sept. Mark trees budded on 9 Aug. and 23 Sept. had ≤ 15% survival. In Washington, scions of M.9 trees budded on 16 July had greater survival than those budded at the last two dates. Scions of Mark trees budded on 23 Sept. in Washington had lower survival than those budded on earlier dates.

Leader diameter in October was not affected by the rootstock or budding date in Illinois (Table 3). However, in Washington, Mark trees budded on 23 Sept. had greater leader diameter than those budded at earlier dates. Leader diameters of M.9 trees grown in Washington were similar among all budding dates.

In Illinois, the length of the leader of Mark trees budded on 9 Aug. was greater than that of Mark trees budded in September and M.9 trees budded in July and two dates in August (Table 3). In Washington, the length of the leader was not affected by the budding date on either rootstock.

M.9 trees budded in September in Illinois had greater total scion growth than all other trees except M.9 trees budded on 30 Aug. (Table 3). Scion growth of Mark trees was similar among all budding dates. In Washington, scion growth was not affected by budding date on Mark or M.9 rootstock.

M.9 trees budded in September in Illinois had more branches (> 5 per tree) than M.9 trees budded in July or

Mark trees budded on 16 July, 9 Aug., or 23 Sept. (Table 3). In Washington, none of the M.9 trees produced branches. In contrast, Mark trees produced up to 3.9 branches per tree, but the number of branches did not differ among budding dates.

In Illinois, Mark rootstock produced greater union overgrowth than M.9 (Table 3). Mark trees budded in July had greater scion overgrowth than those budded in August. M.9 trees budded in July had greater scion overgrowth than those budded in September. In Washington, Mark trees budded in September had less overgrowth than Mark trees budded earlier. M.9 trees had similar overgrowth at all budding dates.

Discussion

Data recorded in May indicated that a high percentage of trees produced scion growth when budded in July or August in Illinois. However, major tree losses occurred by the end of the growing season. An earlier study revealed that 'Jonagold'/Mark trees budded in July and August established vascular continuity by early spring, but exhibited wilting thereafter (8). Scion wilting was attributed to parenchyma tissue in the xylem that restricted water uptake beyond the undifferentiated tissue. Although unions were not examined for a tissue aberration in this experiment, the symptoms of scion wilting were similar to those observed in the previous study. It is interesting to note that a relatively high percentage of scion wilting occurred on M.9 trees as well as on Mark trees in Illinois. In Washington, scion wilting on Mark rootstock is apparently related to the budding date. Twenty-nine per cent of the Mark trees budded on Aug. exhibited scion wilting, whereas $\leq 5\%$ of Mark trees budded at other dates had wilted growth. Wilting was not observed with either rootstock on the last two budding dates in Washington.

At both nursery locations, the optimal time of budding Mark rootstock appears to be in late August. Although survival was low in Oct. 1991 for trees budded on 30 Aug. 1990, especially in Illinois, this budding date tended to be superior to other dates tested. The low percentage of tree survival in Illinois may be attributed to the stressful growing conditions. Extremely warm temperatures in early May may have exacerbated scion wilting. In a study conducted during 1989-1990, scion growth was observed in May on 91% of the 'Empire'/Mark trees that were budded on 31 Aug. (Warmund, unpublished data).

Few scions produced growth in the spring after budding on Mark rootstock on 23 Sept. This apparent lack of union formation may be attributed to insufficient growth of rootstock and/or scion tissues in the fall. Similar results (13% bud-take) were observed when 'Empire' was budded onto Mark rootstock on 21 Sept. 1989 in Illinois (Warmund, unpublished data). 'Jonagold'/Mark trees budded in mid-September in Washington also failed to form a union (8).

Although data from the two locations can not be compared statistically in this study, the results indicate that the optimal budding period for M.9 rootstocks may differ. Only 68% of the M.9 rootstocks budded on 23 Sept. produced scion growth in early May in Illinois. However, by the end of the growing season, M.9 trees budded in September tended to have greater survival, branch number, and total scion growth than trees budded at earlier dates. Trees that had low bud-take in May may have had better growth in October because there was more space for each surviving tree in the field and less competition for sunlight, moisture, and nutrients. In contrast, M.9 trees budded in mid-July in Washington had greater survival than those budded at the last two dates. However, total scion growth on M.9 rootstock was not affected by budding date since these trees failed to produce lateral branches in Washington.

Overgrowth is produced when the cambium of the rootstock or scion divide at unequal rates, resulting in more xylem and phloem elements in one part of the tree than the other at the union (7). In this study, scion and rootstock tissues were not examined to determine the origin of the overgrowth. However, Mark rootstock had greater union overgrowth than M.9 in Illinois. Thus, in spite of a common parent, Mark has a greater genetic tendency for overgrowth than M.9. Overgrowth is apparently unrelated to incompatibility (9).

In conclusion, the optimal time of budding 'Empire' is apparently site and rootstock dependent. Survival of 'Empire'/Mark trees was enhanced when the rootstock was budded on 30 Aug. at both nursery locations. However, 'Empire'/M.9 trees budded in Illinois in September generally had greater survival, scion growth, and number of lateral branches at the end of the growing season than trees budded earlier. In Washington, M.9 rootstocks budded on 16 July had greater tree survival than those propagated on 30 Aug. or 23 Sept.

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Effect of Heat on Wax and Ca Uptake

'Golden Delicious' fruit was pressure infiltrated with Ca either without or 4 days at 38C showed that heat treatment changed the pattern of surface wax. Wax from non-treated fruit exhibited numerous deep surface cracks forming a network on the surface. Since the treated fruit had no network of cracks and contained less Ca, heat treatment presents a problem if Ca is to be pressure infiltrated. The results suggest that cracks are in important pathway for Ca entry. From Roy et al. *HortScience* 29:1056-1058.