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Cultivar Influences Early Rootstock and Scion Survival of Grafted Black Walnut

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Abstract

Black walnut (*Juglans nigra* L.) is being increasingly planted and cultivated in the midwestern USA for the economic potential of both its wood and nuts. Trees that are established for nut production have greater potential for long-term productivity and profit if they are grafted to superior nut-producing cultivars. While numerous productive cultivars have been identified that perform well as scions, advances have not yet been made toward developing superior black walnut rootstocks. Furthermore, very little is known about how various black walnut scion or rootstock cultivars may interact with each other and their environment. The objective of this study was to evaluate early transplant performance of black walnut scion-rootstock combinations at four sites, and to determine which cultivars or cultivar-graft combinations may be best for successful establishment of new plantings. A total of 327 trees comprising 20 different black walnut scion-rootstock graft combinations transplanted at four locations in Missouri (spring 2001) and Arkansas (fall 1999) were selected for analysis. All trees were pre-grafted, and consisted of potted two-year-old seedling rootstocks of known female parentage (open-pollinated seeds from named cultivars), and one-year-old scions of superior, named nut-producing cultivars. Rootstock and scion survival at all sites was assessed in fall 2002. Seedlings from the cultivar 'Kwik-Krop' survived significantly better as rootstocks (83%) than did seedlings from 'Sparrow' (51%), 'Thomas' (57%), and an unimproved nursery-run rootstock (65%), but rootstock source did not affect survival of specific scion cultivars. Among trees on surviving rootstocks, 'Kwik-Krop' scions survived better (96%) than did 'Surprise' (79%) or 'Emma K' (80%) scions. Over the entire range of rootstocks, trees with 'Thomas' scions had better rootstock survival (79%) than 'Sparrow' (63%), 'Kwik-Krop' (63%), and 'Surprise' (53%) scions. These results suggest that rootstock seed source is an important consideration for successful establishment of grafted black walnut plantings, and that scion cultivar might also influence early transplant survival.

Black walnut (*Juglans nigra* L.) is an economically important tree native to east-central North America, valued both for its lumber and nuts. The species holds increasing promise for commercial nut production as advances in both nut-producing scion cultivar development and orchard management continue. Markets for high-quality, thin-shelled nuts are expanding, and grafted black walnut orchards are being planted throughout the midwestern USA in response. However, for managed nut production to become economically viable, substantial horticultural and genetic improvements are needed (19, 20). While some aspects of black walnut genetics and orchard management are being addressed, development of rootstock genotypes with superior horticultural potential has been neglected. The use of rootstocks with proven advantages for graft and transplant establishment will be an important component in the development of black walnut as an economically viable nut crop. Knowledge of scion-rootstock graft combinations that offer the best opportunity for rapid and successful establishment of orchards across a wide range of environments is equally important. Black walnut rootstocks are presently derived only from seeds because methods for asexual rooting of cuttings and tissue culture propagation have not been commercially developed. Controlled pollination of potential rootstock seed parents has likewise not been established because it is not economically practical with current technology. Thus the use of open-pol-

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linated seeds from high quality scion cultivars will likely provide the best prospects for superior black walnut rootstocks until other technologies are advanced.

Several studies (e.g., 4, 5, 6, 10, 23) have documented differences in survival and early growth of non-grafted transplanted black walnut seedlings from various genetic sources established principally for timber production. However, very little information is available on potential rootstock or scion genetic influence on survival and early growth in grafted trees planted for nut production. Three reports (3, 7, 24), which contain some preliminary data from the four plantings used in the present study, constitute most of the published data on black walnut scion-rootstock cultivar interaction. Coggeshall et al. (7) determined that pre-grafted trees with 'Kwik-Krop' and 'Thomas' scions survived transplanting better than 'Surprise' scions across two sites in Missouri, and that transplanted Kwik-Krop seedling rootstocks survived better than Sparrow seedling rootstocks. However, no differences in early tree growth attributable to scion or rootstock cultivar were detected. Thomas et al. (24) reported that survival of 'Emma K' scions was affected by rootstock cultivar at two Arkansas locations, and that site tended to influence survival of 'Emma K' and 'Thomas' scions. Brauer and Jones (3) also observed differences in scion cultivar survival at one Arkansas site, with 'Thomas' scions performing best, and 'Ogden' and 'Kwik-Krop' the worst among seven cultivars. That study also found significant cultivar differences in early growth among scion cultivars.

Other reports of genetic influence on black walnut rootstock performance are unknown, as is the practical application of any putative rootstock cultivar benefit in new or established commercial orchards. However, some tree nurseries have anecdotal evidence of the superiority of certain black walnut cultivar seedlings in producing more vigorous rootstocks (W. Lovelace, Forrest Keeling Nursery, Elsberry, MO, personal comm.). The rootstock production systems used in a related, more commonly cultivated species, Persian walnut (*Juglans regia* L.), which include tissue culture, interspecific hybrid rootstocks, and interspecific graft combinations, may offer guidance or promise for black walnut, but have yet to be investigated. Some studies (13, 14, 22) have shown genotypic advantages in survival, vigor, and uniformity with certain rootstocks used for *J. regia* scions, which suggest that similar improvements for *J. nigra* rootstocks may be possible.

While black walnut trees can often be successfully established with potted, nursery-grown transplants, their survival rarely approaches 100%. Furthermore, the transplanting of grafted trees usually results in the mortality of a small but substantial percentage of scions within the first two establishment years. In our experience, black walnut rootstocks and scions that survive the initial two years after transplanting have a very high chance of continued survival and establishment (unpublished data). Most black walnut orchards for nut production are presently established by field-grafting scions onto young field-established rootstocks, where graft success is highly dependent on weather, skill of the grafter, and other factors. The technique of rapidly establishing nut orchards with potted, pre-grafted trees has yet to become widespread, most likely due to the high cost of such trees, but also due to the routine failure of a significant percentage of both rootstocks and scions. This failure rate, coupled with the additional expected cost of replacement trees, or the time, effort, and skill required to field-graft rootstocks that lost their scions, present substantial obstacles to this industry. The objective of this study was to evaluate early rootstock and scion survival within 20 black walnut graft combinations transplanted at four locations, and to determine which cultivars may be best for successful establishment of new nut orchards.

Materials and Methods

Four grafted black walnut orchards were established in Missouri and Arkansas, USA in spring 2001 and fall 1999, respectively, to study, among other things, scion-rootstock cultivar interactions and early transplant survival. The locations were New Franklin and Mt. Vernon, Mo., and Fayetteville and Booneville, Ark. (Fig. 1). Potted, pre-grafted, nursery-grown trees were used at all locations. Trees for both Arkansas sites were acquired from Forrest Keeling Nursery (FKN, Elsberry, Mo.), whereas the trees for the two Missouri sites were produced in a nursery at the University of Missouri Horticulture and Agroforestry Research Center (HARC, New Franklin, Mo.). The FKN rootstocks were produced by the

Figure 1. Locations (central USA) of the four grafted black walnut plantings used in this study.

Root Production Method (RPM®), where seedlings are temporarily grown in tall, bottomless pots in order to stimulate a vigorous fibrous root system (16). The HARC rootstocks were grown in a similar manner, and similar grafting methods were used at both nurseries. The only notable difference in the production of the two tree sources was that the FKN trees were produced by grafting scions onto seedlings that had been potted the previous summer, whereas at HARC, scions were grafted onto trees that had been potted only 10 weeks prior to grafting. In all cases, transplanted trees consisted of two-year-old rootstocks and one-year-old scions. The two Arkansas sites and the two Missouri sites were established as independent studies, but because of the similarity of all four sites, and the paucity of comprehensive data on black walnut genetic influence on transplant survival, we combined data from all four sites to establish a more substantial data set for analysis.

Site descriptions. New Franklin, Mo. The site is at the University of Missouri-HARC near New Franklin in central Missouri (lat. 39°02’N, long. 92°74’W, altitude 197 m), in USDA Hardiness Zone 5. Precipitation at the site averages 975 mm annually. The soil was a Marshall silt loam (fine-silty, mixed, mesic, Typic Hapludolls), a deep, well-drained, gently sloping, upland soil with moderate permeability and high water-holding capacity that formed on deep deposits of loess (11). Site preparation began in summer, 2000, when all vegetation was killed with glyphosate herbicide, followed by fall seeding of an orchardgrass - timothy (*Dactylis glomerata* L. - *Phleum pratense* L.) mixture. The 180 trees for this orchard were transplanted on 20 Feb. 2001, with a 9.1 × 9.1 m spacing, covering 1.5 ha. Twenty scion-rootstock combinations were replicated nine times across the site in a randomized complete block design. Trees were not irrigated. Weeds within a 1 m radius of the tree were controlled with glyphosate herbicide applied twice annually. Each tree was fertilized annually in spring with 60 g slow-release 13N–5.6P–10.8K fertilizer. All 180 trees were used in the final analysis.

Mt. Vernon, Mo. The site is located at the University of Missouri-Columbia’s Southwest Research Center near Mt. Vernon in southwest Missouri (lat. 37°05’N, long. 93°53’W, altitude 337 m), in USDA Hardiness Zone 6. Mean annual precipitation during the past 45 years was 1,106 mm (8). The soil was an alluvial Huntington silt loam (fine-silty, mixed, mesic Fluventic Hapludolls) that is deep, level, well-drained, and rarely flooded (15). A soil test at planting indicated pH 6.5, organic matter 1.9%, cation exchange capacity 9.0 meq/100g, neutralizable acidity 1.0 meq/100g, and adequate levels of P, K, Ca, and Mg. The site was prepared by killing existing vegetation with glyphosate herbicide in fall 2000, disking and leveling the soil, then seeding to 'Benchmark' orchardgrass. Although the orchard was designed for 120 trees comprising six replications of 20 scion-rootstock combinations, only 92 trees were available for the initial planting. All 92 trees were used in the final analysis. The trees were transplanted on 28 Feb. 2001, with a spacing of 9.1 m × 12.2 m, and covered 1.4 ha. Trees were hand-watered using trucked water during periods of extreme heat and drought within the first two summers. Weeds and vegetation within a 1 m radius of the trees were controlled with glyphosate herbicide applied twice annually. Alleys between trees were managed for orchardgrass hay which was harvested twice annually. After planting, and annually thereafter, 67 kg ha^{-1} N was applied to the hay crop between trees and 60 g 14N–4.2P–11.6K slow-release fertilizer was applied to each tree in mid-spring.

Fayetteville, Ark. The site is at the Arkansas Agricultural Research and Extension Center at Fayetteville, northwest Arkansas (lat. 36º05'N, long. 94º11'W, altitude 376-390 m), in USDA Hardiness Zone 6. Slope at the site is south-facing, ranging from 1-8%. Average annual precipitation is 1,119 mm (18). Soils at the site formed from loamy deposits and cherty limestone residuum. Most of the site is mapped as Captina silt loam (fine-silty, mixed, mesic Typic Fragiudults), which has a fragipan beginning at depths of 40 to 60 cm that results in seasonally perched water tables near the soil surface (12). Soil tests revealed an initial mean pH of 5.3 and adequate levels of P, K, Ca, and Mg. Site preparation began when glyphosate herbicide was applied in April and July 1999 to kill existing vegetation. Lime (4.5 metric ton ha^{-1}) was incorporated into the site Aug. 1999, which elevated soil pH to 6.7 one year later. The site was seeded to wheat (*Triticum aestivum* L.) in fall 1999, and to 'Benchmark' orchardgrass in Sept. 2000. Within a large planting that included additional tree species and multiple studies, 91 potted black walnut trees comprising 17 graft combinations were transplanted 16 Nov. 1999 into five rows 15 m × 9.1 m, covering 1.25 ha. Planting holes (30 cm diameter × 50 cm deep) were augered, and one Right Start fertilizer packet (10 g 16N–2.6P–6.6K; Treessentials, Mendota Heights, MN) was placed at the bottom of each hole before planting. Landscape fabric (1.3 × 1.3 m) was placed around each tree to control weeds. Alleys between the tree rows were managed for orchardgrass with hay crops harvested twice annually. The eastern half of the site and rows (which ran east-west) received 4.5 metric ton ha^{-1} fresh poultry litter (2-3% N) and the western half 56 kg ha^{-1} N (as NH_4NO_3) annually each spring. Trees were not provided with additional fertilizer. During the first two growing seasons, trees were irrigated by filling 20-L buckets (with 3-mm drip holes in bottom) placed next to trees with water as needed. Thirty of these trees, with graft combinations most common among the four sites, were selected and used in the final analysis.

Booneville, Ark. The site is located at the USDA-ARS Dale Bumpers Small Farms Research Center, near Booneville, in west-central Arkansas (lat. 35°06'N, long. 93°56'W, altitude 152 m), in USDA Zone 7. The site is upland, with a 5% slope. Mean annual precipitation at the site is 1,140 mm. The soil at the higher elevation is an Enders silt loam (clayey, mixed, thermic Typic Hapludults) that transitions into a Leadvale silt loam (fine-silty, siliceous, thermic Typic Fragiudults) down-slope. Both soils are classified as being of low natural fertility, deep, moderately well drained, with slow water permeability and medium water-holding capacity (9). The chief difference between the two soils is the presence of a compact and brittle fragipan in the subsoil of the Leadvale at 40 to 90 cm. Analyses indicated that the soil was deficient in P. Therefore, 148 kg ha^{-1} P (as triple superphosphate) was applied before chisel plowing and leveling the site in Nov. 1999. Planting holes (0.3 m diameter × 1 m deep) were augered in rows 12.2 m apart with 7.6 m within rows. The 0.7 ha orchard was planted 6 Dec. 1999 and contained 72 trees of 12 different graft combinations; 25 trees with graft combinations most common across the four sites were used in the final analysis. At planting, one Right Start fertilizer packet (10g 16N–2.6P–6.6K) was placed at the bottom of each hole. The alleys between tree rows were managed for bermudagrass (*Cynodon dactylon* L.) hay production. Each year, mixed fertilizer yielding 67 kg ha^{-1} N, 14.5 kg ha^{-1} P, and 27.9 kg ha^{-1} K was applied in early May, followed by 76 kg ha^{-1} N (as NH_4NO_3) in the second half of July. Two cuttings of hay were removed annually. In addition to the fertilizer applied to encourage hay production, the trees received an additional 57 g 10N–4.3P–8.3K fertilizer in June, late July and early September. Weeds and vegetation within a 1 m radius of each tree's trunk were controlled with glyphosate herbicide in March, June and late July each year. Well water was delivered to the trees as needed via a drip irrigation system.

Study design. A total of 435 grafted black walnut trees with 30 different scion-rootstock combinations was planted among the four sites. A subset of 327 of these trees comprising 20 different scion-rootstock combinations with the most replicates across all four sites was selected for statistical analysis. The 20 graft combinations selected included all possible combinations of five scion cultivars ('Emma K', 'Kwik-Krop', 'Sparrow', 'Surprise', and 'Thomas') grafted onto each of four rootstock types (Kwik-Krop open-pollinated (OP) seedlings, Sparrow OP seedlings, Thomas OP seedlings, and unimproved nursery-run seedlings of Missouri origin).

Survival of all 327 trees at the four sites was documented in fall 2002, after two seasons' growth at the Missouri sites and three seasons' growth at the Arkansas sites. The survival of each tree in the study was rated in two ways: whole tree survival which was indicative of rootstock survival, and scion survival if the rootstock also survived. Survival of all rootstocks was compared with and without regard to which scion cultivar was grafted onto them, and rootstock influence on scion cultivar survival was determined. Likewise, scion cultivars that were grafted onto any of the various rootstocks were compared among each other, with and without regard to rootstock. A more refined subset of 15 specific scion-rootstock cultivar combinations comprising 265 trees was also evaluated to elucidate any beneficial or negative graft survival interactions. Finally, planting sites were compared, and location by rootstock and scion cultivar interactions were determined.

The data distribution was a binomial factor (survival or no survival) for the rootstock and scion of each tree. Trees were grouped by scion cultivar and separately by rootstock cultivar before performing a logistic analysis of variance. Because of unequal numbers of graft combinations among the four sites, the statistical analyses were performed on the more balanced survival odds ratios rather than straight percent survival (1, 17). The survival odds ratios were determined by calculating the antilog (e^x) of the difference between the least squares means estimates. These odds ratio differences were tested using the GENMOD statistical procedure (SAS Institute, Cary, NC), in which the distribution was binomial and the link function a logit. Differences among odds ratios were significant if the chi-square probability was 0.05 or less. A more balanced representation of percent survival was calculated by back-transforming from the odds ratio as follows: % = odds / (1 + odds).

Results and Discussion

A summary of important growing season weather factors at the four sites during the study is presented in Table 1. No clear temperature or precipitation patterns emerged that would largely explain survival results among the four sites, but the region typically endured prolonged rainfall in spring and periods of very hot dry weather during summer, both of which can put severe stress on newly transplanted trees. Overall survival of the 327 transplanted grafted trees across the four sites ranged from 42% at Fayetteville to 84% at Mt. Vernon (Table 2). On some trees, the scion died while the rootstock survived, with scion survival on surviving rootstocks ranging from 85% at New Franklin to 95% at Booneville. Clearly, specific site characteristics are more important to rootstock survival than to scion survival. Specific rootstock- or scion cultivar-

Table 1. Average daily maximum summer temperatures and summer precipitation at the four trial locations during 2000 to 2002.

	Summer high temperature (°C)[z]				Summer precipitation (mm)[y]			
Location	Normal[x]	2000	2001	2002	Normal[x]	2000	2001	2002
New Franklin	30.6	29.3	29.4	30.4	299	447	421	387
Mt. Vernon	30.6	30.3	31.8	31.1	309	392	211	240
Fayetteville	30.7	30.7	31.2	31.3	290	427	269	173
Booneville	33.6	33.8	33.8	32.5	256	263	161	265

[z] Average daily maximum temperature during June, July, and August
[y] Total precipitation during June, July and August
[x] Long-term means (June, July, and August) for each site; 50 years' data for New Franklin, 45 for Mt. Vernon, and 30 for Fayetteville and Booneville

Table 2. Survival (fall 2002) of rootstocks and scions from grafted black walnut trees transplanted in fall 1999 or spring 2001, comprising 20 rootstock-scion combinations at four locations in Missouri and Arkansas.

		Surviving rootstocks		Surviving scions on surviving stocks	
Location	Tree No.	%	Odds ratio	%	Odds ratio
New Franklin	180	56	1.26 bc[z]	85	5.79 a
Mt. Vernon	92	84	5.34 a	86	5.92 a
Fayetteville	30	42	0.71 c	87	6.46 a
Booneville	25	72	2.55 ab	95	19.46 a

[z] Odds within a column followed by the same letter are not significantly different ($P \leq 0.05$).

by-site interactions were inconclusive (data not shown). While the four sites all have generally similar temperate climates, site-specific factors, such as soil type, precipitation, irrigation, and other management factors varied, and apparently had a profound influence on the survival of transplanted black walnut, regardless of cultivar.

Across all four sites and all scion cultivars, Kwik-Krop OP seedling rootstocks had a significantly higher odds of survival compared with the other three rootstock types (Table 3). Interestingly, the unimproved nursery-run rootstock performed as well as Sparrow and Thomas OP seedling rootstocks, both of which are known regionally as vigorous, productive scion cultivars (26). The fact that the nursery-run rootstock seeds were from local trees that are likely better adapted to the region may have compensated for any putative genetic superiority of Sparrow and Thomas seedlings as rootstocks in these trials. 'Sparrow' originated as a wild seedling from northwestern Illinois, whereas 'Thomas' originated from southeastern Pennsylvania (2). 'Kwik-Krop' is from southeastern Kansas in a region drier than our study area, which might help explain its early survival success in this region. Table 3 further indicates that rootstock cultivar did not significantly affect scion survival. Data in Table 4 suggest that scion cultivar can also influence the odds of rootstock (and therefore whole tree) survival, with 'Thomas' scions performing better than 'Sparrow', 'Kwik-Krop', or 'Surprise'. The apparent influence of scion cultivar on rootstock survival is dif-

Table 3. Influence of black walnut rootstock source on rootstock and scion survival (fall 2002) among trees planted at four locations in Missouri and Arkansas in fall 1999 or spring 2001.

		Surviving stocks		Surviving scions on surviving stocks	
Rootstock seed source	Tree No.	%	Odds	%	Odds
Kwik-Krop	90	83	4.87 a[z]	92	11.89 a
Sparrow	75	51	1.04 b	83	4.91 a
Thomas	100	57	1.33 b	86	6.07 a
Nursery run	62	65	1.82 b	92	12.15 a

[z] Odds within a column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4. Influence of black walnut scion cultivar on rootstock and scion survival (fall 2002) in grafted trees planted at four locations in Missouri and Arkansas in fall 1999 or spring 2001.

		Surviving stocks		Surviving scions on surviving stocks	
Scion cultivar	Tree No.	%	Odds	%	Odds
Thomas	69	79	3.78 ab[z]	88	7.15 bc
Emma K	58	67	2.02 bc	80	3.90 c
Sparrow	66	63	1.71 c	89	8.10 bc
Kwik-Krop	78	63	1.67 c	96	26.35 ab
Surprise	56	53	1.13 c	79	3.85 c

[z] Odds within a column followed by the same letter are not significantly different ($P \leq 0.05$).

ficult to understand and explain; perhaps there are some heretofore unknown genetic, vigor, or graft compatibility factors that may prove advantageous to trees with ‘Thomas’ scions. When looking specifically at scion survival regardless of rootstock (Table 4), ‘Kwik-Krop’ had better odds of survival than ‘Emma K’ or ‘Surprise’, but not ‘Thomas’ or ‘Sparrow’.

For Tables 5 and 6, we analyzed a more refined subset of 265 trees, individually comparing the 15 scion-rootstock cultivar combinations that were most common across all four sites. Table 5 once again underscores the better survival of trees with Kwik-Krop OP seedlings as rootstocks. Interestingly, the two best performing rootstock-scion combinations consisted of a scion cultivar grafted onto seedling rootstocks of that same cultivar (‘Kwik-Krop’/Kwik-Krop OP, and ‘Thomas’/Thomas OP). Perhaps genetically similar graft combinations provide better compatibility between the two tissues, in some cases, compared with more diverse grafted material. Seven graft combinations had less than a 1:1 odds of rootstock survival across all four sites, suggesting that certain cultivar combinations do have survival and establishment advantages over others. While there were a few differences in scion survival among the various graft combinations, notable patterns did not emerge (Table 6). Clearly, the influence of scion cultivar was less important than rootstock in survival of a transplanted grafted tree.

Why is survival of grafted, transplanted black walnut trees often so poor? Site selection and management factors are obviously very important to the survival of potted, grafted black walnut transplants. Study of specific site

Table 5. Rootstock survival (fall 2002) among 15 scion-rootstock graft combinations planted at four locations in Missouri and Arkansas in fall 1999 or spring 2001.

			Surviving rootstocks	
Scion	Rootstock seed source	Tree No.	%	Odds
Kwik-Krop	Kwik-Krop	27	91	9.81 a[z]
Thomas	Thomas	28	86	6.13 ab
Thomas	Kwik-Krop	15	84	5.37 abc
Sparrow	Kwik-Krop	17	84	5.13 abc
Emma K	Kwik-Krop	18	80	4.01 bc
Surprise	Kwik-Krop	13	75	3.00 bcd
Thomas	Sparrow	15	68	2.14 cde
Sparrow	Sparrow	15	52	1.09 def
Sparrow	Thomas	19	45	0.81 ef
Emma K	Sparrow	15	44	0.80 ef
Emma K	Thomas	15	44	0.80 ef
Kwik-Krop	Sparrow	15	37	0.59 f
Surprise	Thomas	15	37	0.59 f
Kwik-Krop	Thomas	23	37	0.58 f
Surprise	Sparrow	15	30	0.43 f

[z] Odds within a column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 6. Scion survival (fall 2002) among 15 scion-rootstock graft combinations planted at four locations in Missouri and Arkansas in fall 1999 or spring 2001.

			Surviving scions on surviving rootstocks	
Scion	Rootstock seed source	Tree No.	%	Odds
Kwik-Krop	Kwik-Krop	21	96	25.84 az
Thomas	Kwik-Krop	14	94	16.64 a
Surprise	Kwik-Krop	10	92	11.45 ab
Sparrow	Sparrow	9	91	10.70 ab
Kwik-Krop	Thomas	11	91	9.83 ab
Sparrow	Thomas	10	90	9.13 ab
Kwik-Krop	Sparrow	8	90	9.08 ab
Thomas	Thomas	22	86	6.28 ab
Thomas	Sparrow	11	85	5.88 ab
Emma K	Kwik-Krop	13	85	5.61 ab
Sparrow	Kwik-Krop	13	81	4.18 ab
Emma K	Thomas	8	80	3.89 ab
Surprise	Thomas	7	77	3.37 ab
Surprise	Sparrow	6	73	2.67 b
Emma K	Sparrow	8	56	1.29 b

[z] Odds within a column followed by the same letter are not significantly different ($P \leq 0.05$).

factors that may lead to failure or success of black walnut rootstocks across various sites is needed to increase orchard establishment success rates to economically viable levels. Further research is also merited to evaluate the physiological factors that cause rootstocks and grafts to fail after transplantation, and how such failures may be ameliorated. For example, perhaps some sort of added physical protection for delicate graft union tissues during the establishment years could improve scion survival. While we did not detect specific location by rootstock or location by scion cultivar interactions, choice of both rootstock and scion cultivar influenced overall transplant survival in this study, and should be considered by growers. Even though scion cultivar apparently influenced transplant survival, genetic factors associated with rootstocks, including rootstock-environment interactions, are likely more important than scion characteristics for transplant survival. Significant differences in scion cultivar characteristics such as vigor, disease and insect resistance, hardiness, nut production, nut quality, precocity, and tree strength have been documented in numerous black walnut cultivars (19, 21, 25). While cultivar selection is important to the initial tree establishment, a wide variety of important genetic and production factors must be considered when selecting both rootstock and scion cultivars for establishment of long-lived black walnut orchards.

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I certify that the statements made by me above are correct and complete. R.M. Crassweller, Business Manager. December 31, 2007.