COMPARISON OF PLANTING METHODS FOR NURSERY- AND CONTAINER-GROWN BLACK WALNUT SEEDLINGS[1/]

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Abstract.--Survival and height growth of container-grown black walnut seedlings were compared with bare root, nursery-grown seedlings using two planting times (fall vs. spring) and two planting methods (bar vs. machine). After 5 years, survival of spring-planted, container-grown seedlings averaged 72 percent compared to 37 percent for spring-planted, nursery-grown seedlings. Conversely, survival of fall-planted, nursery-grown seedlings averaged 67 percent compared to only 37 percent for fall-planted, container-grown seedlings. After 5 years, container-produced seedlings were 10 cm taller than the nursery-produced seedlings. Methods of planting had no effect on survival; however, after 4 years, machine-planted seedlings were taller than bar-planted seedlings.

Keywords: *Juglans nigra* L., containerized seedlings, planting time, survival, bare-root seedlings

INTRODUCTION

Black walnut (*Juglans nigra* L.) seedlings planted as 1-0 bare-root stock typically produce little new shoot growth the first year after outplanting (Bey 1972, Van Sambeek and Rietveld 1982). Poor height growth is caused by inadequate new root regeneration resulting from either the loss of fibrous roots during lifting, dessication during storage, low levels of stored carbohydrates, or poor root/soil contact after outplanting. To overcome some of these problems, container-grown seedlings with an intact fibrous root system could be used instead of bare-root, nursery-grown seedlings. An intact root system offers many more sites for new root regeneration that may be critical for survival and early shoot growth, especially during dry periods.

Container-grown seedlings might also be used to expand the normal planting season to include fall planting. The fibrous root system of container-grown seedlings would anchor the seedling and reduce the incidence of frost heaving--a problem frequently encountered with fall planted bare-root, nursery-grown seedlings (Rietveld and Williams 1981). Although apparently untried, the deep planting of walnut seedlings in the fall might also reduce the incidence of frost heaving; however, deep planting is impractical with most hand implements or commercially available tree planters. Some of the new tree planters, such as the one being developed by Michigan State University, not only deep plant both container-grown and nursery-grown seedlings, they also loosen the subsoil to permit deeper root penetration.

When we began this study in 1980, little information was available on field performance of fall- or spring-planted, container-grown black walnut, and no studies compared their growth with 1-0 nursery-grown seedlings. We designed our study to compare effects of spring and fall planting

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using either machine- or bar-planting on survival and early height growth of both container-grown and nursery-grown walnut seedlings on a compacted, somewhat poorly drained site in southern Indiana. This questionable walnut site was chosen to stress the seedlings, accentuating differences between treatments.

MATERIALS AND METHODS

Container-grown black walnut seedlings were grown in 6 x 6 x 30 cm polyethylene-coated paperboard plant bands in a Michigan State University greenhouse according to techniques described by Wood and Hanover (1981). Briefly, 200 germinating walnut seeds were sown one per cavity in March 1980 for the fall-planting and another 200 seeds were sown in June 1980 for the spring-planting. Seedlings were grown in Rediearth (a commercial peat-vermiculite soil mix) under continuous fluorescent light during the normal dark period. After approximately 4 months, seedlings were hardened-off for approximately 3 months and then stored at 4° C until outplanted. The plant bands were removed at the planting site, disturbing the seedling root system as little as possible; however, the planting medium frequently fell away from the roots before the seedlings were planted.

In October and December 1980, 200 bare-root, nursery-grown seedlings grown from the same seedlot were lifted from the nursery beds at the Vallonia Forest Nursery near Brownstown, Indiana. Seedlings were root-pruned to a uniform length of 20 cm, packaged in poly-lined Kraft paper, and stored at 1° C until outplanted.

Half the seedlings were planted on November 14, 1980 and the remaining half were planted on March 25, 1981. At each planting time, half the seedlings were planted with KBC bars, and half were planted with the new Michigan State University tree planter. The MSU tree planter opened a trench approximately 15 cm wide and 20 to 25 cm deep. Because the soil was wet when the seedlings were planted in both the fall and spring, a member of the planting crew had to follow the tree planter to firm the soil around each seedling.

The planting site was a compacted, poorly drained old field site in Johnson County, Indiana. The soil was a mixture of Crosby (fine, mixed, mesic, Aeric Ochraqualfs) and Miami (fine-loamy, mixed, mesic, Typic Hapludalfs) silt loams. Before the fall planting, the planting site was strip-sprayed with the postemergent herbicide glyphosate (2.5 l ai per ha) in 1-m-wide bands at 3-m intervals. After the March 1981 planting, all rows were strip-sprayed with the preemergent herbicide simazine (4.5 kg ai per ha). No additional weed control was done.

Treatments were composed of four replications for all combinations of two seedling types (nursery-grown vs. container-grown), two planting seasons (fall vs. spring), and two planting methods (machine vs. hand). Planting method was a subtreatment within main treatments of seedling type and planting season. Thirty-two 25-tree row plots were established with trees 1 m apart within rows and 3 m apart between rows.

Seedling survival was evaluated in the spring after all seedlings were planted and after each growing season. Regardless of the amount of stem dieback, seedlings were considered alive if cambial tissue was active at the root collar. Total stem height was measured in the spring after all seedlings were planted and after each growing season. Frost heaving (exposed root collar), basal sprouting, and animal damage were assessed for each seedling in the spring after all seedlings were planted and after each growing season.

Variation was analyzed as a split-plot experiment using plot means to determine if differences among treatments existed within main effects ($p \leqslant 0.05$) or their interactions ($p \leqslant 0.01$). Percentages were analyzed following arcsine transformation for $n < 50$. Significant interactions were analyzed following procedures in Steel and Torrie (1960) for partitioning the sum of squares into treatment within seedling type.

RESULTS

Survival

In April 1981, after all the seedlings had been planted, a significant interaction for seedling survival already existed among seedling type and planting time (table 1). More than half of the fall-planted, container-grown seedlings failed to overwinter or died during the first growing season (fig. 1). This interaction between seedling type and planting season for seedling survival persisted through the fifth growing season. Partitioning the sum of squares within seedling type revealed that fall-planted, nursery-grown seedlings had better survival than container-grown seedlings for all 5 years. Conversely, spring-planted, container-grown seedlings had better survival than nursery-grown seedlings after the third through the fifth growing seasons.

Annual Mortality Rates

After the first growing season (1981), the annual mortality among the surviving container-grown seedlings tended to be less than that for the nursery-grown seedlings. Annual mortality rate of seedlings surviving the 1981 growing season failed to show differences among treatment combinations during the 1982 growing season, but significant differences were found during the 1983 and 1984 growing seasons (table 2). During the 1983 growing season, mortality for spring-planted, nursery-grown seedlings exceeded that for spring-planted, container-grown seedlings. During the 1984 growing season mortality for both the fall-planted and spring-planted nursery-grown seedlings

Table 1.--F-values[1] from analysis of variance for seedling survival, annual mortality, and height after outplanting through the fifth (1985) growing season.

Dependent variables	Source of variation: Main treatments: Seedling type	Main treatments: Planting season	Main treatments: Type x season	Subtreatments: Planting method	Subtreatments: Method x type	Subtreatments: Method x season	Subtreatments: Method x type x season
Survival							
Spring 1981	39.09**	30.58**	34.52**	2.88	1.40	1.39	2.82
Fall 1981	97.52**	92.62**	100.51**	1.50	3.32	4.98*	0.02
Fall 1982	25.78**	29.49**	51.38**	0.31	0.15	3.40	0.73
Fall 1983	13.32**	11.51**	82.59**	0.24	0.17	3.52	0.60
Fall 1984	0.06	0.10	39.76**	1.37	0.99	0.57	0.15
Fall 1985	0.19	0.14	31.48**	1.27	2.16	0.32	0.22
Annual mortality							
1981	59.37**	58.65**	56.74**	1.70	2.35	3.88	0.01
1982	3.30	1.09	4.18	0.10	0.92	0.15	2.26
1983	3.42	7.39*	9.01*	3.76	2.30	1.17	0.17
1984	12.53**	5.37*	0.54	2.58	2.00	0.35	0.92
1985	2.31	1.67	3.67	0.30	1.60	0.10	0.03
Height							
Spring 1981	105.00**	0.02	4.08	5.40	2.10	0.74	2.73
Fall 1981	108.27**	0.28	1.43	1.22	1.25	0.89	3.26
Fall 1982	8.45*	3.01	0.31	0.02	0.13	1.55	0.40
Fall 1983	7.89*	27.00**	0.12	4.28	1.38	1.09	0.59
Fall 1984	20.64**	15.02**	0.73	9.38*	1.27	2.58	1.11
Fall 1985	17.84**	10.87**	0.80	11.60**	0.53	5.35*	0.08

1/F-values followed by an * or ** indicate significant differences exist among treatment combinations at the $p \geqslant 0.05$ and $p \geqslant 0.01$ levels, respectively.

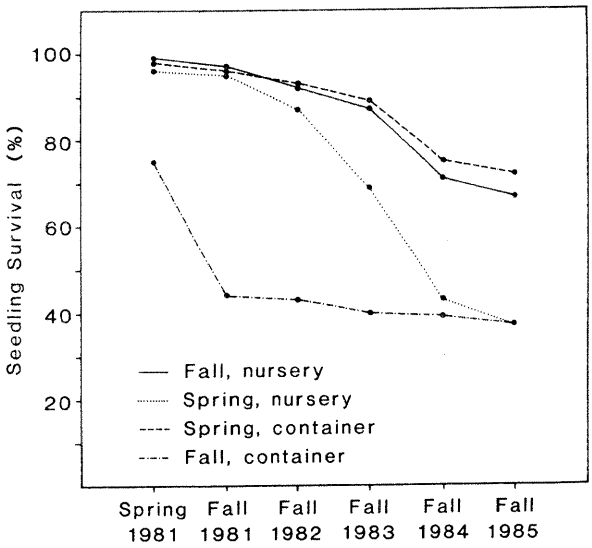

Figure 1.--Survival of nursery-grown and container-grown seedlings planted in the fall or spring through the first five growing seasons.

Table 2.--Percentage annual seedling mortality by treatment combinations for third and fourth growing seasons.

Treatment combinations: Seedling type	Planting: Time	Planting: Method	Annual mortality rate: 3rd year	Annual mortality rate: 4th year
			- - - - %	- - - -
Nursery	Fall	Hand	5	23
		Machine	3	12
	Spring	Hand	25	45
		Machine	12	33
Container	Fall	Hand	6	9
		Machine	6	3
	Spring	Hand	6	16
		Machine	4	17

continued to exceed that for the container-grown seedlings. In addition, the 1984 mortality among spring-planted seedlings exceeded that for the fall-planted seedlings. There were no significant differences in annual mortality rates between the hand-planted and machine-planted seedlings.

Whether the root collar remained buried or not may have influenced initial survival and annual mortality. Over 18 percent of the seedlings had exposed root collars after the first growing season, ranging from 50 percent in the fall-planted, container-grown seedlings planted with KBC bars (hand) to only 1 percent for the fall-planted, nursery-grown seedlings planted with KBC bars (table 3). Differences in percentages of seedlings with exposed root collars probably were caused more by improper planting in a thick thatch than by frost heaving. Only 1 percent of the nursery-grown seedlings hand-planted in the fall had exposed root collars, suggesting that little frost heaving occurred at this planting site. When all treatments were combined, 40 percent of the seedlings with exposed root collars died during the first three growing seasons compared with only 14 percent of seedlings with buried root collars. In addition, more fall-planted seedlings with exposed root collars died than did spring-planted seedlings with exposed root collars (52 vs. 17 percent, respectively).

Table 3.--Percentage of seedlings by treatment combinations with exposed root collars after the first growing season.

Treatment combinations			Exposed root collars
Seedling type	Planting Time	Planting Method	
			- % -
Nursery	Fall	Hand	1
		Machine	30
	Spring	Hand	3
		Machine	6
Container	Fall	Hand	50
		Machine	13
	Spring	Hand	19
		Machine	15

Height Growth

Although nursery-grown planting stock was significantly larger than the container-grown planting stock, extensive dieback and seedling resprouting resulted in no significant differences in average seedling height after two growing seasons (fig. 2A). During the 1983 growing season, most treatments with container-grown seedlings showed net positive height growth, while most treatments with nursery-grown seedlings continued to die back or show net negative height growth.

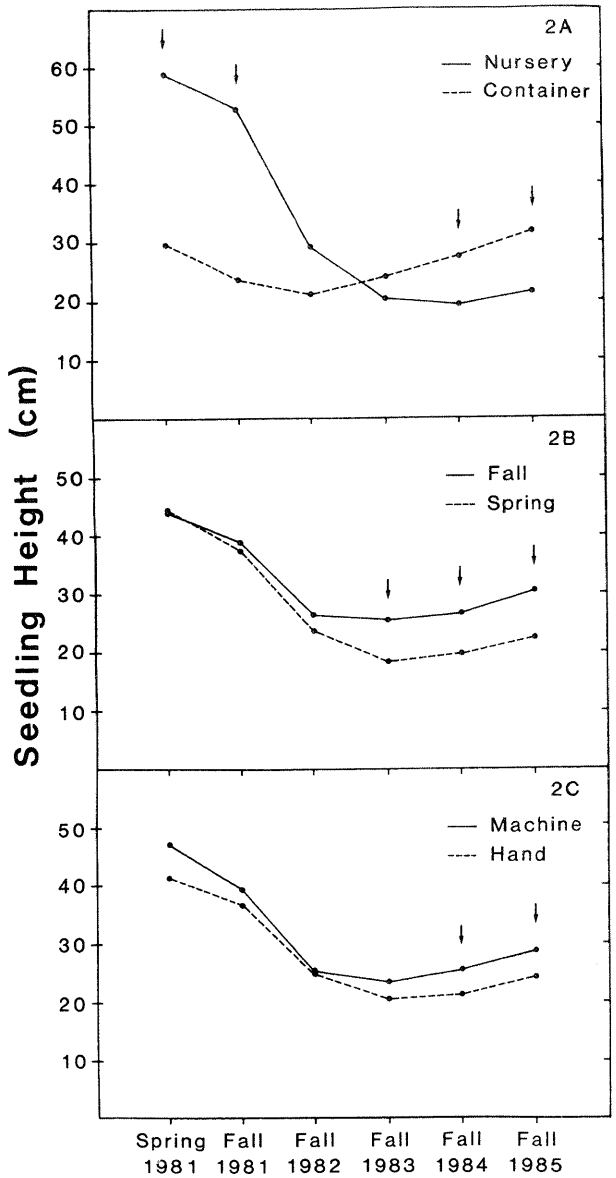

Figure 2.--Average seedling height for nursery-grown and container-grown stock (2A), for fall-planted and spring-planted seedlings (2B), and for hand-planted and machine-planted seedlings (2C) from the spring of 1981 after all seedlings were planted through the 1985 growing season. An arrow indicates when means are significantly different from each other at the $\alpha = 0.05$ level.

After the 1985 growing season, container-grown seedlings were 10 cm taller than the nursery-grown seedlings.

Differences were found in seedling height between fall-planted and spring-planted seedlings after the 1983 growing season and between the hand-planted and machine-planted seedlings after the

1984 growing season (figs. 2B and 2C, respectively). These differences persisted through the 1985 growing season, with the result that fall-planted seedlings were 8 cm taller than the spring-planted seedlings and machine-planted seedlings were 4 cm taller than the hand-planted seedlings.

The differences in seedling height may have been confounded by low seedling survival within some treatment combinations where only the larger, more competitive seedlings survived. Comparison of initial seedling heights for seedlings dead or alive after the third growing season showed no significant differences within any of the eight treatment combinations. Likewise, comparison of seedling height after the third growing season for surviving seedlings with and without a buried root collar revealed no significant differences within any of the eight treatment combinations.

DISCUSSION

When we began our study in 1980, we recognized the potential benefits of using container-grown seedlings; however, little information was available on field performance of container-grown black walnut seedlings. Interpretation of earlier research was further complicated because the container-grown seedlings used were either conditioned, actively growing stock or dormant, hardened-off stock (von Althen and Prince 1986, Anderson et al. 1983). Dormant, hardened-off stock was used in our study because conditioned, actively growing stock cannot be successfully planted in the fall. Although our container-grown planting stock was smaller than our nursery-grown seedlings, the container-grown seedlings were similar in size to container-grown seedlings produced by other researchers using ambient CO_2 levels and similar sized containers (Funk 1971, McQuilkin 1974, von Althen and Prince 1986).

Our spring-planted, container-grown seedlings survived better than the spring-planted, nursery-grown seedlings on our questionable walnut site. Similar results were obtained by Anderson et al. (1983) for container-grown black walnut and red oak on reclaimed minelands. Anderson et al. (1983) attributed the high initial mortality of their nursery-grown seedlings to frost heaving, but frost heaving was apparently not a problem in our study. The poor initial survival of our fall-planted, container-grown seedlings suggested that our stock was not sufficiently hardened-off for late fall planting or that the hand-planting was poorly done.

Our container-grown seedlings initiated net positive height growth sooner than the nursery-grown seedlings. A similar result was also found for container-grown walnut by Anderson et al. (1983) on reclaimed minespoils and by von Althen and Prince (1986) on a good walnut site. Failure of our container-grown seedlings to initiate net positive height growth sooner may have resulted from removing the tarpaper container and subsequent loss of the planting medium. We removed the containers because previous studies had shown that walnut root growth was often restricted if the containers were not removed (Ellis 1972, McQuilkin 1974). Recently, von Althen and Prince (1986) found that wet tarpaper presented no barrier to walnut root penetration and growth. Based on this information, we probably should not have removed the tarpaper containers in our study.

The machine-planted seedlings were taller than the bar-planted seedlings after the 1985 growing season. None of the seedlings were excavated; therefore, we can only presume that the subsoiling action of the Michigan State University tree planter has resulted in deeper root penetration and increased height growth.

CONCLUSIONS

Container-grown black walnut seedlings have the potential to outperform nursery-grown seedlings; however, the high costs associated with production and outplanting will restrict use of container-grown seedlings to situations where seedlings of high value are grown or where rapid early height growth is important. Container-grown planting stock adapt sooner to a planting site than bare-root, nursery-grown planting stock.

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