Influence of Seed Position on First-Year Survival and Growth of Directly Seeded Northern Red Oak

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A study was conducted in Quebec to select the best technique for sowing northern red oak (Quereus rubra *L.*) *in the field. This study examined the effect of planting position on seedling growth and the direct seeding methods to achieve the best early survival and growth. The seed positions tested were sideways and with tips down or up. Sowing methods com pared were hand throwing and deposition of seeds through a tube held at 3 different angles (vertical, 45%, and 30%). The recommended sowing method takes into account the survival and growth for three planting positions, the proportion o f seeds landing in the prepared slits, and the sowing time. Acorns planted with tips pointing down resulted in the low-est root biomass, crooked taproots, and the highest shoot-to-root dry weight ratios after the first growing season. Planting position had no statistically significant effect on seedling early survival and growth. Weed competition reduced the straightness o f the taproot. Two sowing techniques were test ed. Sowing was more efficient when seeds were hand-thrown into perpendicular slits cut with a lawn edger.* Tree Planters' Notes 47(2):68-75; 1996.

Direct seeding can be an appropriate means of regenerating northern red oak *(Quercus rubra* L.) on sites where the natural seed supply is deficient, provided that sowing techniques are appropriate (Kolb and others 1989). Various factors, notably site quality, depth of sowing (Auchmoody and others 1994; Schopmeyer 1974; Wilkinson and others 1992), and predation (Johnson 1994; Thorn and Tzilkowski 1991) are thought to affect survival and early growth of oaks. The influence of seed weight has also been extensively studied (Auchmoody and others 1994). The position of seeds as a factor in the survival and early growth of oaks has not been considered. Theoretically, some seed positions could initiate morphological deformation, mainly of the root system. In this article, we seek answers to the following questions:

- What morphological differences in seedlings result from the position of the seed in the ground?
- In which positions do seeds tend to fall?
- Can the proportion of seeds in the best position for

Survival, height growth, dry weights of organs, and number of roots are among the most frequently used variables to assess the success of regeneration (Beck 1970; Gordon 1988; Kolb and Steiner 1989; Stroempl 1985; Trencia 1995). Differences in architectural characteristics of root systems also occur with changes in growth conditions (Fitter and Strickland 1992; Trencia 1995). Topological variables are useful for succinctly describing the architecture of the root system independently of its dimensions. The topological diameter of a root system is the highest number of ramifications from the root collar to the apex of a root tip; it is correlated to the energy cost of building the root system and to the efficiency for water transportation (Fitter 1985). Acorns will germinate on the surface of the ground. However, most unburied acorns are subsequently displaced or destroyed by rodents (Auchmoody and others 1994). Natural burial of red oak acorns is mostly performed by grey squirrels in single--acorn caches in the ground about 3 cm deep (Thorn and Tzilkowski 1991). Recommended planting depth varies from 0.5 to 3 cm (Schopmeyer 1974; Williams and Hanks 1976). Direct seeding of oak usually involves dropping seeds into spots in the soil. The incision can be made with a light instrument. Lawn edgers are well suited for this task (figure 1); they cut to the appropriate depth and are relatively light, inexpensive, and readily available. In this study

- We compare first-year growth of seedlings developing from seeds placed in the soil in 3 positions.
- We also evaluate how sowing techniques may increase the ratio of seeds falling in what is determined as the ideal position.
- We choose a sowing technique that combines efficiency of delivery with optimal positioning of seed for growth.

Materials and Methods

Northern red oak seeds were collected in October 1991 from a single stand located at Sainte-Croix, Quebec. All the seeds were immersed in fresh water for

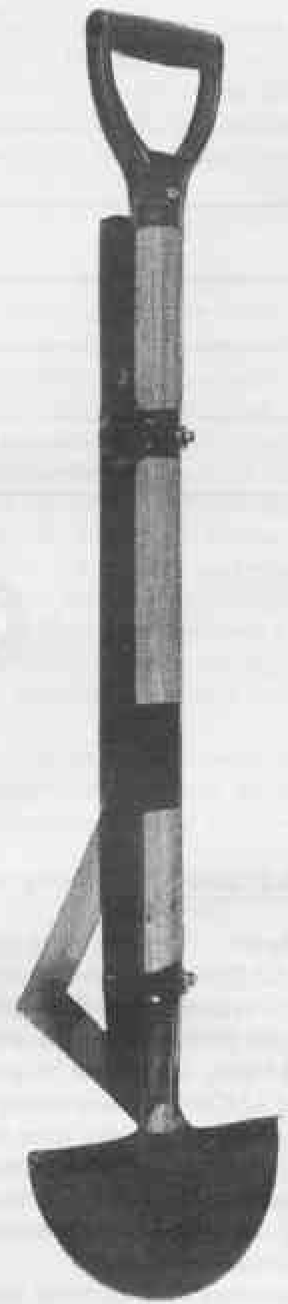

Figure 1—*Lawn edger with tube and triangle attachments*

2 days; floating seeds were then discarded. The healthy seeds were sun-dried and inspected for insect larvae, mainly *Curculio* sp. The seeds were then stored at 5 /C until mid-April 1992 and stratified afterwards (Struve and others 1991).

Sowing was carried out in May 1992. The trials were conducted at Cap-Tourmente (latitude 47/ 04' north, longitude 70/ 48' west), approximately 50 km east of Quebec city. The soil was a loamy clay of the Maheux series (Marcoux 1981), with no clearly defined horizons. The site had been cultivated until 1963; a poplar plantation was subsequently established on it.

The experiment consisted of 1 "biological" trial to assess the growth of seedlings and 3 "direct seeding techniques" trials to evaluate sowing techniques. We used a randomized complete block design, located in a small clearing of a poplar plantation, for the seedling survival and growth trial. The 3 trials of direct seeding techniques comparing the sowing methods were done under planted rows of hybrid poplar, approximately 50 m from the growth trial.

Seedling survival and growth trial. Seedling growth for 3 positions of acorns in the seed spot were replicated 6 times, for a total of 18 cells, in a randomized complete block design (figure 2). The cells consisted of 1 row of 50 seeds, each spaced 15 cm apart within rows and 1 m between rows. The seed positions compared were sideways (position 1) and with tips down (position 2) or up (position 3).

One-year-old seedlings and 4 samples of herbaceous vegetation were collected from each cell of the block design. To extract the seedlings, the surrounding soil was lifted and seedlings were soaked in water to remove the soil from the roots. We analyzed 222 seedlings that did not suffer root breakages at extraction and collected aboveground portions of herbaceous vegetation from 4 small plots of 400 cm^2, 15 cm from each row of seedlings.

The topological diameter of each seedling was calculated as the maximum number of root ramifications from any root tip to the root collar. The angle between the sections above and below the root collar was measured with a protractor. The maximum angle between taproot sections above and below the point of attachment of the acorn was 180/, corresponding to a straight taproot.

All dry weights were measured after oven drying at 110 /C for 24 hours. Variables calculated were total height, stem and root dry weight, topological diameter, angle of deviation of the taproot, and aboveground dry mass of herbaceous vegetation.

Direct seeding techniques. The acorns were spaced about 60 cm apart, the planters sowing a seed with each step. A T-shaped seed spot was created by cutting 2 perpendicular slits in the ground with a lawn edger. Seeds were then directed into the prepared slits either by hand or through a guiding tube attached to the lawn edger (figure 1). The objective of the using a guiding tube is similar to that of the Pottiputki planter, which deposits container seedlings vertically (shoot up) in the intended spot. We assumed that a seed rolling within the tubing would turn on its side and fall in that position into the slit. Seeds were also expected to roll better if the tube was held at an angle instead of vertically.

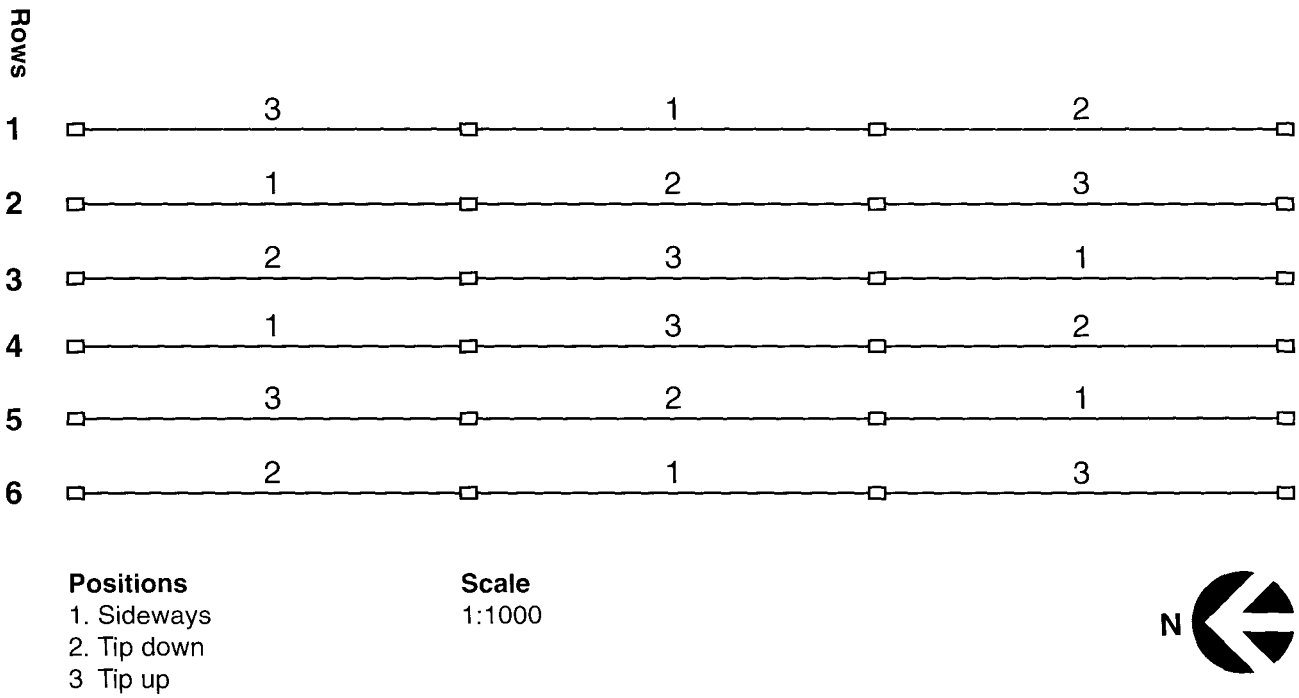

***Figure 2**—Experimental layout of the seedling survival and growth trial.*

Thus, attaching a tube to the side of the lawn edger seemed to be a low-cost practical way of controlling the location and positioning of acorns. The seed positions were the same as in the growth trial: acorns on their sides (position 1) or with tip down (position 2) or tip up (position 3).

In the first trial of direct-seeding techniques, we looked at how the angle of the guiding tube relative to the soil affected the positioning of the seeds in the slit. The design compared the effect of 3 angles of the seeding device (vertical, 45/, or at 30/) and of the 2 operators. The angle was controlled with an appropriate triangle attached to the handle (figure 1).

In the second trial of direct-seeding techniques, we compared the 2 different sowing methods: hand-throwing the seeds into the slits or depositing them through the tube attached to the lawn edger's handle. Because we believed that the operators would improve with practice, we sowed 2 replications of 50 seeds. We recorded the number of seeds falling in the intended location (that is, in or out of the slit) and the position of seeds in the slits. Thus, the 2 sowing methods, the 2 operators, and 2 replications were tested in this second trial.

In the third trial of direct-seeding techniques, we compared the time it took to sow batches of 100 acorns by hand or through the guiding tube mounted on a lawn edger. The layout was a randomized complete block design with 2 operators, 2 sowing techniques, and 4 replications.

Statistical analysis. Statistics were computed using SYSTAT, version 5.2 (Wilkinson and others 1992). All values of F and chi square higher than the threshold values of 5% and 1% probability levels were considered as significant and highly significant, respectively.

In all the initial ANOVA models testing seedling growth, the independent variables were the treatment (that is, the seed positions), replication and biomass of herbaceous vegetation (VegGM2). Survival results were normalized using the weighted logit transformation for small samples (Fernandez 1992).

For all variables other than survival, cell values were averaged over all the seedlings of the cell. For each significant ANOVA, orthogonal contrasts tested 2 hypotheses. First, growth for positions 1 and 3 did not differ. Second, growth for position 2 differed from that of the 2 other positions.

Significant factors of the first 2 direct-seeding-techniques trials were determined using log linear models. These models compared the predicted and observed number of seeds in each position or location. The models retained showed no significant difference at P values above 0.05, according to Agresti (1990) between the observed and predicted values and

In the last direct-seeding-techniques trial we compared sowing times by analysis of variance, where independent variables were instruments, operators, and replications. In this analysis, interactions were removed from the final analysis because they were not significant.

Results

Seedling survival and growth trial. Median survival after 3 months was 66% for seeds lying sideways and 40 to 44% for seeds placed vertically (figure 3). Weighted logit transformations of survival were not significantly different ($F = 0.886$, $P = 0.44$). Herbaceous vegetation did not affect survival ($F = 4.3$, $P = 0.068$).

Biomass of competing herbaceous vegetation had no significant effect except in relation to the straightness of the taproot ($F = 7.29$, $P = 0.024$). Herbaceous competition, however, was not random and was more important along a line running from centre front (row 3, column 1) to back left of the design (row 6, column 3, figure 4). Topological diameters were slightly different ($P = 0.046$) when the effect of vegetation biomass was not considered.

The seed position had no influence on mean height and stem dry weight (table 1). For the morphological characteristics considered (table 1), there were no significant differences between seedlings from acorns sown sideways (position 1) and with their tip up (position 3). Sowing the acorns vertically with the tips down (position 2) resulted in a reduction of the root dry weight, the straightness of the taproot (figure 5), and the topological diameter. Lower root dry weight increased shoot to root ratio for acorns sown tips down, compared with acorns in the other 2 positions.

Seeding techniques trials. In the first seeding techniques trial, we determined that the operator and the angle of the tube used to deposit the seeds had no effect

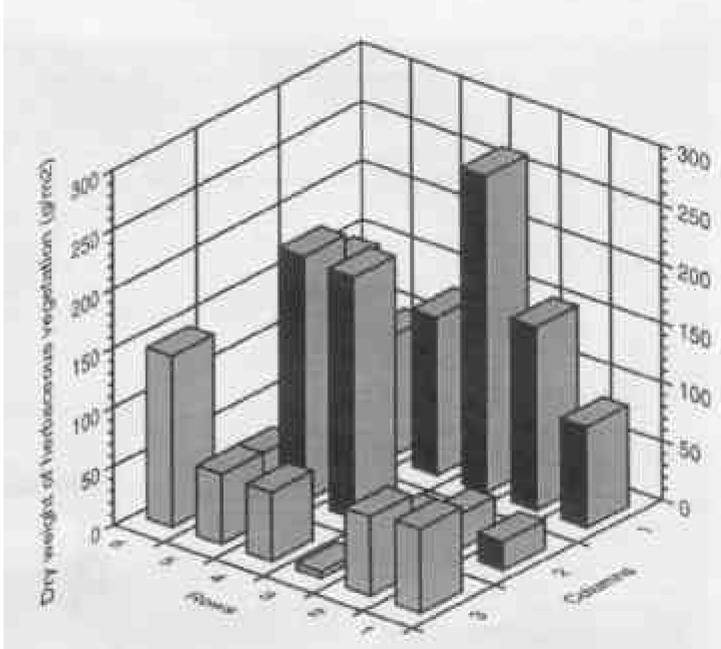

Figure 4—*Dry weight of herbaceous vegetation for the cells of the randomized complete block design. Distances between rows and columns are not to scale. The columns' axis represents the southern edge of the design.*

Table 1— *Summary results of analysis of variance for the main characteristics of first-year northern red oak seedlings*

	Values of F		Mean for acorn position		
	Treatment	Covariant[1]	Sideways	Tip down	Tip up
Survival (%)	0.89		55	39	42
Height (cm)	1.80		149	158	142
SDW (&g)	0.53		485	476	432
RDW (&g)	5.04*		637 a	478 b	599 a
S/R (%)	9.37**		84 a	111 b	79 a
Angle[2] (degrees)	7.04*	7.29*	159 a	110 b	136 a
Diameter[3]	4.24*		101 a	80 b	97 a

SDW = stem dry weight, RDW = root dry weight, S/R = shoot-to-root dry weight ratio. Means for acorn position followed by different letters are statistically different at the 5% probability level. The asterisks (*) and the double asterisks (**) indicate significant (5% probability level) and very significant (1% level) differences respectively.

[1] Dry weight of aerial parts of herbaceous vegetation per square meter (g/m2).

[2] Deviation of taproot from a straight line.

[3] Topological diameter (Fitter 1985).

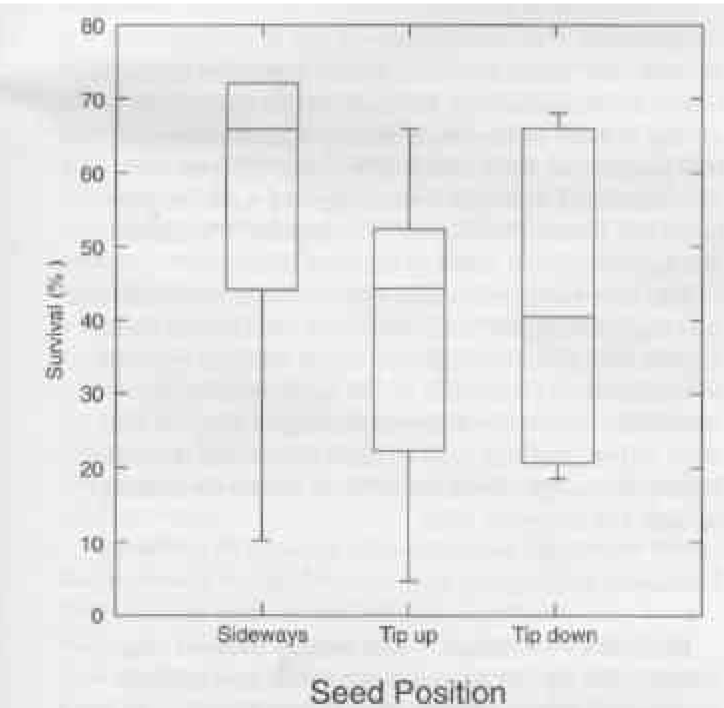

Figure 3—*Box plot of survival ratio per treatment. The horizontal bar in the box shows the median. Upper and lower edges of the boxes represent the 25th and 75th percentiles, respectively, and the bars show the 5th and 95th percentiles.*

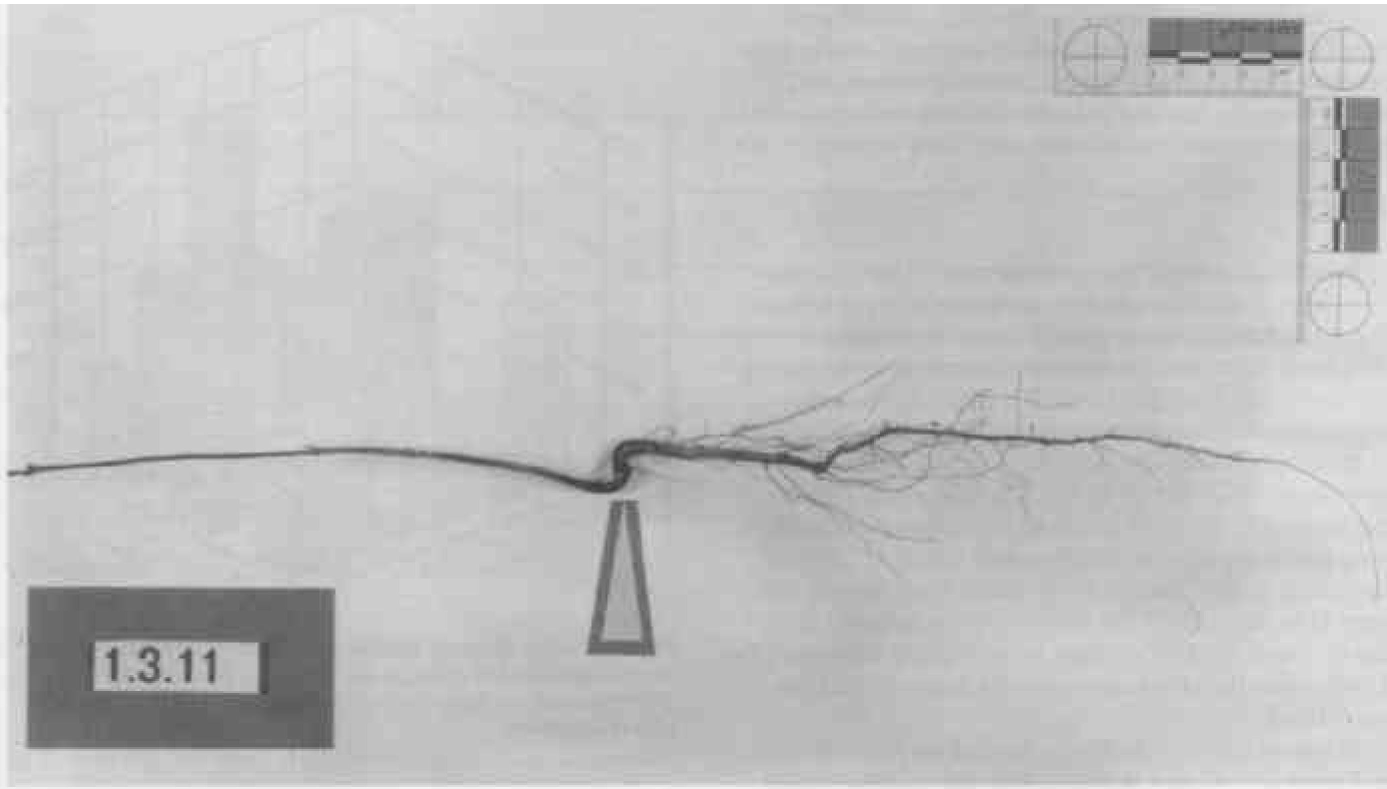

Figure 5—*Angle between the sections of the taproot above and below the junction with the radicle. The seedling represented was planted vertically with the acorn's tip pointing downward.*

on the resulting position of the seeds in the slits (table 2); 80% of the seeds fell sideways, 11% with the tips pointing down, and 9% with the tips pointing up.

In the second trial, the proportion of seeds falling onto the prepared seed spot increased with the use of a guiding tube (table 3); 5.9% of the seeds fell outside the intended location when they were hand thrown, where-

Table 2— *Effect of the angle o f the sowing tube with the ground on position of seeds in the ground; significant and nonsignificant variables are determined by log-linear models*

	Independent variables				
Dependent variables	Significant	Non-significant	df	G2	P
Position[1]	—	Angle[2] Operator[3] Position * Angle Position * Operator	15	14.92	0.457

Df = degrees of freedom; P = probability of the maximum likelihood ratio value (G2). The asterisk (*) identifies interactions between 2 variables.
[1] Positions recorded are seeds lying sideways (position 1) or vertically with their tips down (Auchmoody and others 1994) or up (Back 1979).
[2] The variable "angle" compares seeds dropped in a tube placed vertically or at angle of 45 or 30° with the ground.
[3] Two operators planted batches of 100 acorns each.

as only 1.3% landed outside when deposited through a tube. Therefore, sowing through a tube resulted in a saving of 4.6% of the seeds. Seed position, however, was independent of the method of sowing, of operators, and of replications (table 3). Percentages of seeds in positions 1 to 3 were 80, 12, and 8%, respectively, almost identical results to those of the first trial.

The time required to sow 100 acorns in the third trial was significantly reduced when the seeds were handthrown into the slits: adjusted mean number of seeds sown decreased from 275 to 230 seeds/person-hour when the seeds were directed through a tube on the lawn edger. The 20% gain in time with hand throwing largely outweighs the loss of 5% of the seeds landing outside the intended spot.

Discussion

Growth of seedlings. Our results showed that pointing the tips of acorns down while sowing had detrimental effects on root growth and possibly, on seed germination. However, sowing technique had no influence on this because the seeds tended to fall in the same position whether they were hand thrown in the slits or sown through a tube.

Table 3— *Location and position; significant variables are determined by log-linear models*

Independent variable	Dependent variables: Significant	Dependent variables: Non-significant	df	G2	P
Location [1]	Method Location * method	Operator Replication [2] Location * operator Location * replication Method * operator Method * replication Operator * replication	4	6.02	0.197
Position [3]	—	Method Operator Position * method Position * operator Position * replication Method * operator Method * replication Operator * replication	21	9.32	0.986

The asterisk (*) identifies interactions between 2 variables. df = degrees of freedom. *P* = probability of the maximum likelihood ratio value (G2).
[1] The variable "location" is the frequency of seeds falling in or out of the prepared seed spot.
[2] Two operators planted replicates of 55 acorns.
[3] Positions recorded are seeds lying sideways (position 1) or vertically with their tips down (Auchmoody and others 1994) or up (Beck 1970).

Survival rates were similar to those reported in previous studies (Johnson 1994). Although the survival rate was 20% higher for acorns lying sideways than for the other 2 seed positions, such differences were not significant. Absence of significant differences in survival rate is a consequence of the lowest survival rate values of seeds lying sideways (figure 3). Weed competition can affect survival in different ways. Beck (1970) obtained survival rates of approximately 30% after 2 years when there was no control of competition from low vegetation or overstory In a controlled environment, Kolb and others (1989) reported higher germination rates in the presence of competition. Surveys in forest stands show poor regeneration success when competition from low vegetation increases (Johnson 1994). Our mean values of herbaceous biomass ranged from 60 to 132 g/m^2, compared with 100 to 230 g/m^2 in a study by Kolb and others (1989). Sampling biomass late in the fall when some species (as dandelion) had completely disappeared from our plots may have affected the significance of the effect over survival.

Variations in biomass of herbaceous vegetation were likely caused in part by inter-plot competition. Neighboring trees or herbaceous vegetation may have reduced available light or affected available moisture. This resulted in patches of dense competing vegetation separated by areas with lower biomass values for competing vegetation (figure 4). The influence of competition on survival in our trial can be considered low because the high biomass values in Figure 4 do not match low survival values in figure 6.

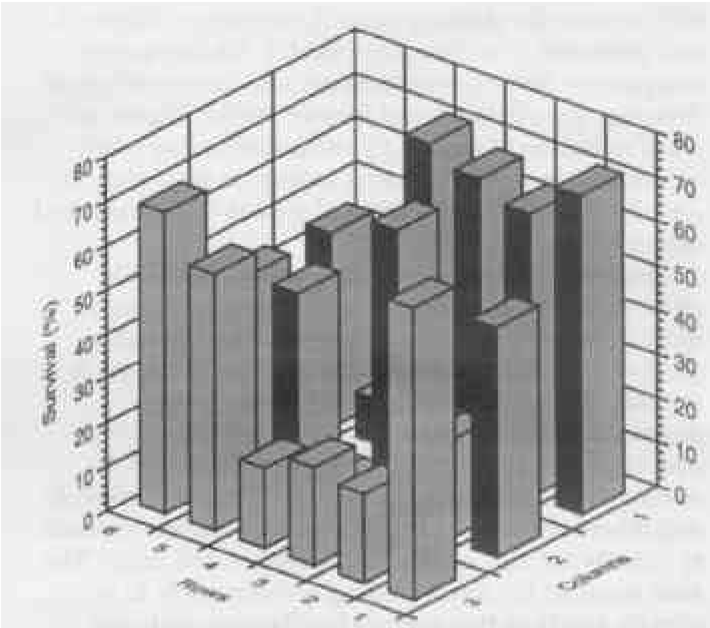

Figure 6—*Survival percentage for the cells of the randomized complete block design. Distances between rows and columns are to scale. The columns' axis represents the southern edge of the layout.*

Our seedlings were relatively small by nursery standards. Seedlings grown in nurseries for 1 season weigh approximately 3 times more than our seedlings (Kolb and Steiner 1989a, Trencia 1995). Heights reported are 2 to 4 times higher than the ones we obtained.

Generally, seed position in the ground does not change aboveground growth of seedlings. Root systems of northern red oak are generally considered as more site-sensitive than the aboveground parts: Kolb and Steiner (1989a) reported that during the first year, red oak has a tendency to modify allocation of its reserves to the production of roots whereas stem growth is controlled genetically. Schultz and Thompson (1990) recommended that northern red oak seedlings not be graded by stem measurements. Sowing seeds with their tips down mainly decreases the straightness of the taproot and the biomass of the root system. One-year-old nursery-grown seedlings generally have shoot-to-root dry biomass values (SRR) ranging from 0.3 (Kolb and Steiner 1989a) to 6.0 (Tworkoski and others 1983). Tworkoski and others (1983) observed 2-fold differences with changes in soil bulk density. Our SRR values diminished mainly with increased root dry weight. Herbaceous vegetation also obstructed the elongation of the taproot vertically and reduced the topological diameter of the root system.

Overall role of weed competition does not appear to warrant efforts to control weeds during the first year. Kolb and others (1989) report that weed competition reduces height growth by 29% for red oak compared to 60% or more for yellow-poplar *(Liriodendron tulipifera* L.) and white ash *(Fraxinus americana* L.). Within-species competition between oak seedling also has no effects on first-year growth (Kolb and Steiner 1989b). Higher levels of reduction of seedling growth warranting weed control are, however, reported mostly on good sites for a study spanning over 3 years of growth (Cogliastro and others 1990).

Sowing techniques. Sowing method had little effect on the positioning of the seeds in the ground: hand throwing the acorns or rolling them through a guiding tube did not modify the position of the seeds in the soil. Sowing through a guiding tube mostly increased the length of time required for the sowing operation. Sowing through a tube also increased the number of acorns buried in the soil by 5%. Auchmoody and others (1994) reported that nearly all seeds exposed to rodents are lost, mostly to chipmunks and mice. The time required for direct seeding is comparable to or slightly less than that needed for planting container seedlings.

Conclusion

The object of this study was to select the best manual method of sowing northern red oak acorns, taking into account biological and technical constraints. The lawn edger proved a useful and appropriate tool for preparing the seed spots in the clay loam soil. Considering that the same number of seeds fell in the best position for seedling growth regardless of sowing method, hand throwing the seeds is recommended because it reduces the sowing time: it took about 20% less time to hand-throw the seeds than to use the planting tube. Our results support seedling grading methods including root systems characteristics. Short-term observations suggest that operational methods should aim at maximizing the proportion of seeds lying sideways. Acorns lying sideways had the best survival although the differences between techniques were not significant. All sowing techniques ensured a good early growth for over 80% of the seeds germinated. In an ideal scenario, only a few seedlings with negative characteristics would originate from seeds with the tips pointing down. We ran the study over one growing season mainly in order to first obtain short-term data. Longer-term studies of 2 or 3 years are needed to evaluate the persistence or appearance of existing or new morphometric differences. In addition, new direct seeding techniques trials could be run in order to find ways of increasing the proportion of seeds that land sideways.

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