Production & Germination of PAPER BIRCH SEED and its Dispersal into a Forest Opening

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KNOWLEDGE of the seed-crop characteristics of paper birch (*Betula papyrifera* Marsh.) is essential to the success of carefully planned silvicultural measures aimed at the natural regeneration of this species. In general, we know how much seed is produced, when it is dispersed, and what its germination characteristics are *(2, 11, 12)*. But more specific information about all three factors is needed to provide silviculturists with a sound basis for developing methods of regenerating paper birch that forest managers can apply successfully.

In 1964, the Northeastern Forest Experiment Station began a 3-year study of the production, dissemination, and germination of paper birch seeds. Results of this study have emphasized the need to consider seed quality as well as germinative characteristics in evaluating seed crops. It has also shown that, in the stands surrounding a clearcutting, most of the seed is dispersed within these stands and that the proportion falling into the clearcutting diminishes rapidly as the distance from the forest edge increases.

The Study Area

The study area was located on the Penobscot Experimental Forest near Orono, Maine. It included a clearcut area 7 chains square surrounded by paper birch seed trees in a forested strip 1 chain wide. The bordering forest, about 75 years old, consisted largely of poletimber-size paper birch and red maple (*Acer rubrum* L.) with a scattering of other hardwoods and softwoods. Average height of the paper birch trees was about 60 feet.

Paper birch trees 5.0 inches in diameter and larger were considered as seed trees. The number of these trees surrounding the clearcutting varied. There were about 149 per acre in the north stand, 107 per acre in the east and west stands, and about 27 per acre in the south stand.

Methods

To estimate the proportion of the paper birch seed crop dispersed at varying distances from each side of the clearcutting, seed traps were located in two strips that bisected opposite sides of the study area. One strip was oriented approximately north and south, the other east and west. These strips were 1 chain wide and 9 chains long, and were divided into 9 blocks of equal size (fig. 1). On each strip, the two end blocks were in the forest stand; the remaining seven blocks were in the clearcutting.

Three small seed traps were randomly located within each block, a total of 51 traps. These traps, 6.5 inches in diameter, were mounted on posts about 3 feet above the ground. They were used only for estimating the number of paper birch seeds dispersed into the clearcutting.

To provide a greater number of seeds for estimating production, germination, and dispersal, four larger traps (16 inches square) were placed on the ground in the residual stand 1 chain from the edge of the clearcutting. One of these traps was placed on the back edge of each end block on both strips.

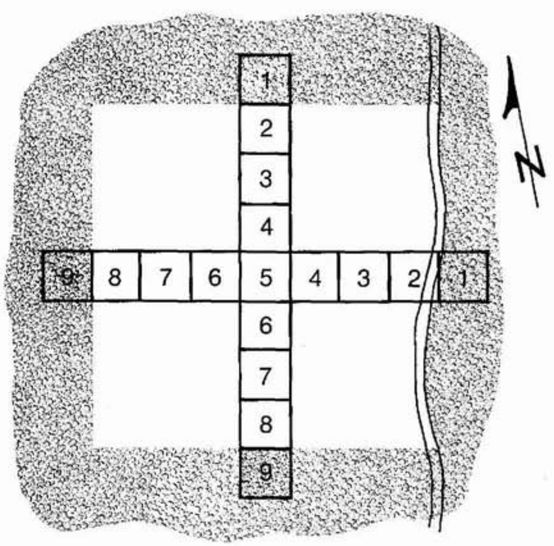


Figure 1.—The two strips of blocks were laid out to bisect opposite sides of the clearcutting.

Seed collections were made weekly from August through November, the period of greatest seedfall *(2)*. Traps were not visited from the beginning of December until spring when the final collection was made.

Immediately after each collection, the paper birch seeds were counted and sorted into one of three seed quality classes: (1) empty seeds that were weeviled or had empty seed coats, (2) discolored seeds with brown or black edges or spots, and (3) good seeds.

All seed collections were carefully marked to show the date of collection, trap number, and quality class. They were then stored in paper envelopes at about 35°F. until after the final seed collection in the spring, when germination tests were made. Whether or not the varying lengths of storage (2 to 10 months) had an unequal effect on germination is not known.

Germination tests were conducted in a darkened germinator set to operate at about 92°F. for 8 hours during the day. Room temperature during the night averaged about 68°F. After slow cooling, the germinator reached this temperature.

Seed Production

Seed production varied among the three seed years and among the stands adjacent to the clearcutting. Production estimates based on the number of seeds trapped within the forest stand ranged from a low of 0.7 million seeds per acre in 1964 to a high of 9.8 million seeds per acre in 1966 (table 1). Paper birch seed production as high as 36 million seeds per acre has been reported *(11)*, although these very heavy crops occur only about once in every 10 years *(4)*. On the other hand, reasonably productive seed years occur about every other year *(2)*.

The seedfall was greatest in the north and east stands, least in the south and west stands. Since the number of female catkins per tree was estimated to be roughly equal in all stands for each year of record, stand composition probably accounts for much of the difference. The south stand had the fewest

Table 1.—*Paper birch seed production by quality class, stand, and seed year*

Seed year	Stand	Quality class			Number per acre
		Good	Discolored	Empty	
		Pct.	*Pct.*	*Pct.*	*Million*
1964	North	53	13	34	2.4
	South	63	15	22	0.7
	East	61	11	28	1.6
	West	69	25	6	1.0
	Average	59	15	26	1.4
1965	North	69	12	19	5.4
	South	66	19	15	1.7
	East	65	12	23	5.2
	West	79	11	10	3.1
	Average	69	13	18	3.9
1966	North	79	14	7	9.8
	South	83	13	4	2.6
	East	86	9	5	9.4
	West	85	13	2	3.1
	Average	83	12	5	6.2

seed trees. The west stand, with the same number of seed trees as the east stand, had a considerable number of hemlocks whose crowns presumably deflected or retained many seeds that otherwise would have fallen into the seed traps. The prevailing winds might also have affected seed distribution. Coming from the southwest, these winds might have blown seeds beyond the traps for the south and west stands.

To put seed production in its proper perspective, it must be considered in terms of seed quality. In this study, poor-quality seeds (discolored and empty combined) accounted for 14 to 47 percent of the total seed crop. Discolored or empty seeds result from a variety of causes that can occur from the start of flowering in the spring until bud formation in the fall. Adverse weather conditions, poor pollination, failure of fertilization, diseases, and insects all play a part. Whether or not seed quality depends on the size of a seed crop is not entirely clear. But in this study, high seed production in 1966 was associated with a substantial reduction in the proportion of empty seeds.

Germination

Germination tests were made of the paper birch seeds from the larger traps within the forest stands to estimate the effects of seed year, seed quality, and time of dispersal on seed viability. Both germinative capacity and germinative energy of the seeds were determined for each seed-quality class.

Germinative capacity is the percent of seeds germinating, regardless of time *(12)*. For seeds of good quality, this was better in the more productive seed years and better for seeds dispersed in late fall and winter (table 2). Although there were too few discolored seeds for a completely reliable test, the results suggested that their germinative capacity was lower than for good seeds.

Germinative energy is the percent of seed germinated at the time the trend of germination reaches its peak *(12)* and the germinative energy period terminates with the rapid and constant decrease in daily germination *(10)*. Because it accounts for rapidity of germination, germinative energy is probably a better measure of the worth of a seed crop than is germinative capacity.

Table 2.—*Germinative capacity of paper birch seed by seed year and month of dispersal*

Month of seed dispersal	Seed year		
	1964	1965	1966
	Pct.	*Pct.*	*Pct.*
Aug	27	48	43
Sep	34	55	45
Oct	40	69	69
Nov	63	67	72
Dec to spring	77	65	68
Average	49	65	64

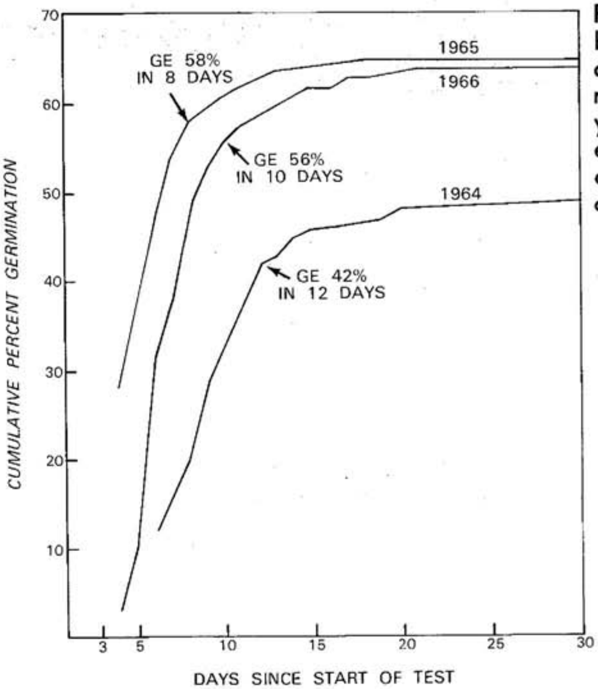


Figure 2. — Germination begins sooner and proceeds more rapidly in the more productive seed years. The germinative energy (GE) and the end of the GE period are indicated.

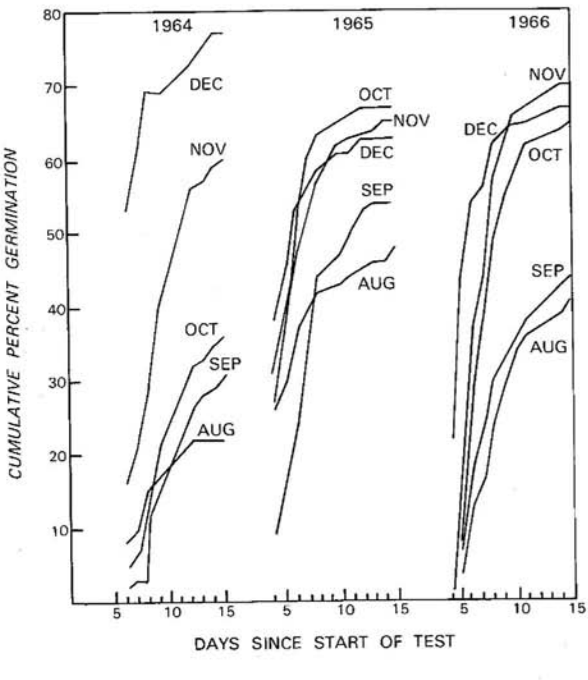


Figure 3.—Germination is faster and greater for seed dispersed in late fall and winter.

Germination tests showed that, in the better seed years, the germinative energy of good seed not only reaches higher levels than the poor-quality seed, but germination begins sooner and proceeds more rapidly than in less productive seed years (fig. 2). Germinative energy of the seed also varies by month of dispersal: as the dispersal season progresses, the germinative energy improves (fig. 3). These are important factors in regeneration, because seedlings that germinate long before the onset of summer heat and drought have a better opportunity for survival. Limited tests of discolored seeds suggest that these seeds germinate at a much slower rate.

Time of Dispersal

In general, relatively small amounts of seed fall early in the dispersal period. As the season progresses, seedfall increases

Table 3—*Dispersal of the paper birch seed crop by month of dispersal, stand, and year*

Seed year	Stand	Percent of total seedfall					Total
		Aug	Sep	Oct	Nov	Dec - spring	
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1964..........	North	5	8	47	24	16	100
	South	7	39	17	29	8	100
	East	21	43	15	19	2	100
	West	1	9	12	45	33	100
	Average	9	22	28	27	14	100
1965..........	North	7	15	27	46	5	100
	South	17	12	50	17	4	100
	East	7	10	51	28	4	100
	West	9	9	54	18	10	100
	Average	11	12	43	29	5	100
1966..........	North	10	10	30	17	33	100
	South	12	15	42	26	5	100
	East	6	13	11	68	2	100
	West	4	10	50	30	6	100
	Average	8	12	27	38	15	100

rapidly to a peak and then decreases sharply as the end of the dispersal period approaches.

The proportion of the seed crops dispersed in any month varied by forest stand and by year in this study (table 3). But for all stands combined, most of the paper birch seeds fell in October and November. Time of dispersal did not appear to depend on the size of the seed crop.

Seed Dispersal Pattern

In general, most of the paper birch seed crop fell within the forest stand (fig. 4). In this study, and for sampling areas of the same size, 3.5 to 7.1 times as much seed fell in the forest as in the clearcut area.

As distance from forest edge increases, the amount of seed decreases rapidly. To describe this pattern of seed dispersal, a regression analysis was made of the seedfall on distance from

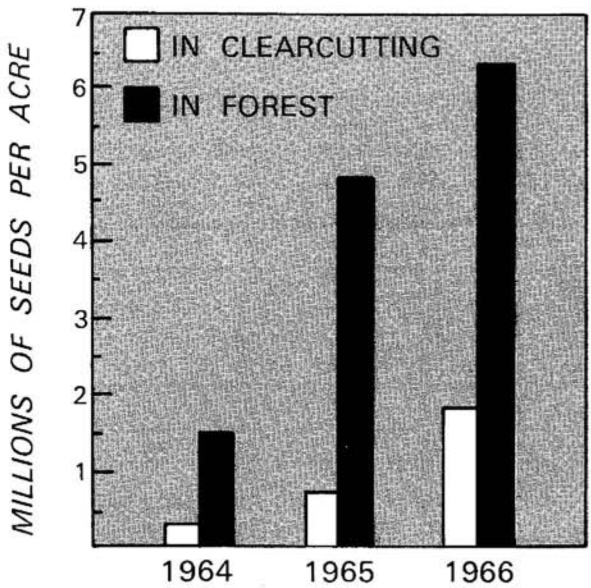


Figure 4. — Most paper birch seed falls within the forest stand rather than in an adjacent clearcutting.

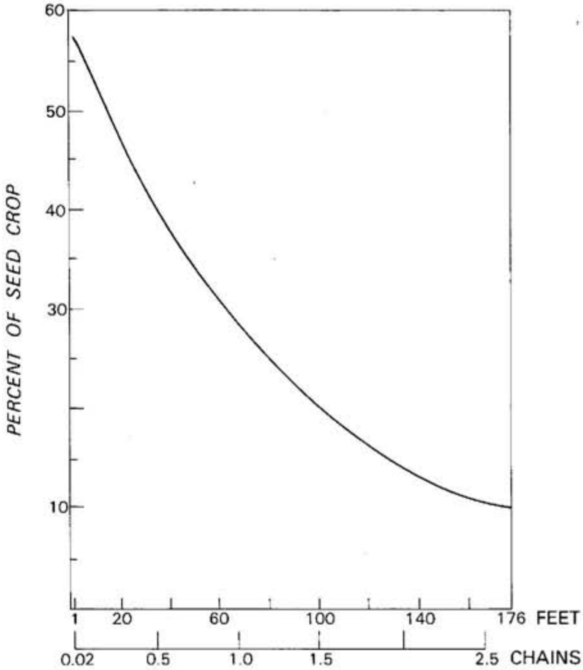


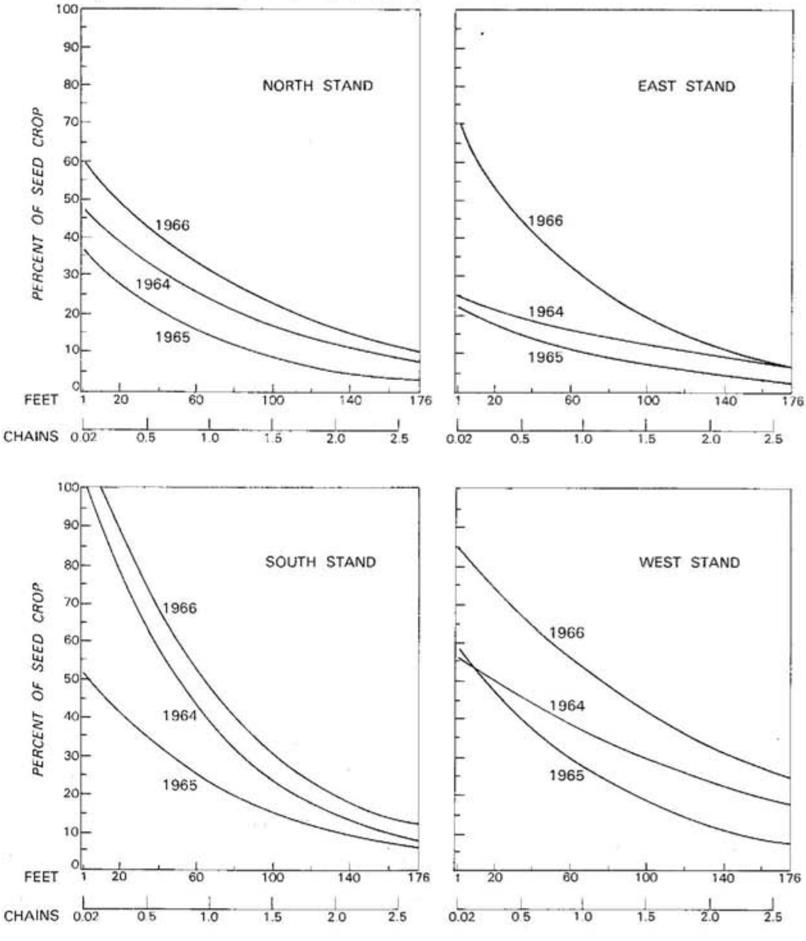
Figure 5.—The percent of the seed crop dispersed into the clearcutting drops off rapidly as the distance from forest edge increases. In this case, the coefficient of determination (r^2) is 0.62.

forest edge. The seedfall at any distance from this edge was described as a percentage of the seedfall within the forest stand. Regression equations showing the seed-dispersal pattern for each of the four stands in each of three seed-years were then derived by least squares. An additional equation for all stands and all years combined was also obtained.

To illustrate the average dispersal pattern, consider the curve (fig. 5) for the combined data. Adjacent to the forest stand, the seedfall amounted to 58 percent of that within the stand. As the distance is increased to a maximum of 176 feet, only an estimated 10 percent might be expected to fall. Similar curves for each stand and seed-year (fig. 6) emphasize the variability that might be expected.

The coefficient of determination (r^2) of 62 percent for the combined data indicates that distance from forest edge presents a reasonable picture of expected seed dispersal into a clearing.

Figure 6.—The proportion of the paper birch seed crop dispersed various distances into the clearcutting varied by forest stand and by seed year.



In only three individual cases — the east stand in 1964 and 1965, the south stand in 1965 — was distance not a good estimator of seed distribution into the clearing (table 4). Apparently some unmeasured factor influenced distribution in these cases. However, seedfall was strongly associated with distance, and these curves can be useful in predicting amounts of seed that might be expected at varying distances from the forest edge.

In general, the tendency for the amount of paper birch seed

Table 4.—*Coefficients of determination (r^2) for distance from edge of clearcutting and percent seedfall*

Forest stand	Coefficients of determination		
	1964	1965	1966
	Pct.	*Pct.*	*Pct.*
North	70	71	83
East	29	39	98
South	64	53	80
West	78	86	61

to decrease sharply with an increase in distance from the forest edge is similar to that reported for other species.

The seedfall of yellow birch (*Betula alleghaniensis* Britton) at the edge of a forest opening was reported to be 6 times greater — and sugar maple (*Acer saccharum* Marsh.) 4 times greater — than the seedfall of these species 5 chains into a clearcutting *(1)*. The effective dispersal distance of *Betula verrucosa* Ehrh. and *Betula pubescens* Ehrh. was established as twice the height of the seeding trees *(8)*. Similar results have also been reported for some softwoods *(3, 6, 7, 9, 13)*.

Silvicultural Implications

The seed crop data presented here have some important silvicultural implications in the regeneration of paper birch stands. By using these data, we can make a better evaluation of the seed crop in terms of dispersal distance, seed quality, and germination characteristics. These factors, combined with an estimate of how much seed is required for satisfactory regeneration, will aid in determining the type of regeneration cutting to be made.

What constitutes an adequate quantity of seed depends on the probability of seedling establishment; and a single estimate to cover all situations is not practical. The paper birch seed production and germination data reported here, added to that already published *(2)*, will help to provide reasonable estimates.

Since one-half or more of the seed crop is dispersed in October and November, all site preparation aimed at regenerating a paper birch stand should be completed by that time. By doing so, the seeds will be more likely to find a receptive seedbed and soon be protected and stratified by a snow cover. Also, since germinative energy is greater for seed falling in these months than it is earlier, seed collections should be made at this time.

Work done with *Betula verrucosa* and *Betula pubescens (8)* indicates that a seedfall of 100 to 200 filled seeds per square meter may be required if a maximum number of seedlings is to be produced by natural regeneration without special site preparation. This is equivalent to an average of 600,000 viable seeds per acre or, adjusted for seed quality, a total of 630,000 to 800,000 seeds per acre. Using this estimate, we can determine fairly easily the effective seed-dispersal distance for seed crops of varying size.

To illustrate: first read the percent of total seedfall for various distances from the curve in figure 5. In practice, the curve selected should be the one that comes closest to the user's situation. Multiply the estimated seed crop by the percent factor to determine the number of seeds per acre at the selected distance. Then plot these data as in figure 7. This figure shows that a seed crop of 2 million seeds per acre would be effectively dispersed a distance of 0.50 to 0.75 chains from the forest edge. A seed crop of 8 million seeds per acre would be effectively dispersed slightly over 2.5 chains.

If paper birch is to be regenerated in clearcut strips, then figure 7 can be used to estimate the width of strip that will be effectively seeded. Assuming equal dispersal from both sides of the strip, crops of 2 million and 8 million seeds per acre would effectively seed strips 1.0 to 1.5 chains wide and about 5 chains wide respectively.

These estimates are conservative because they apply to undisturbed seedbed conditions only. Forest managers should adjust these estimates to reflect the influences of seedbed condition,

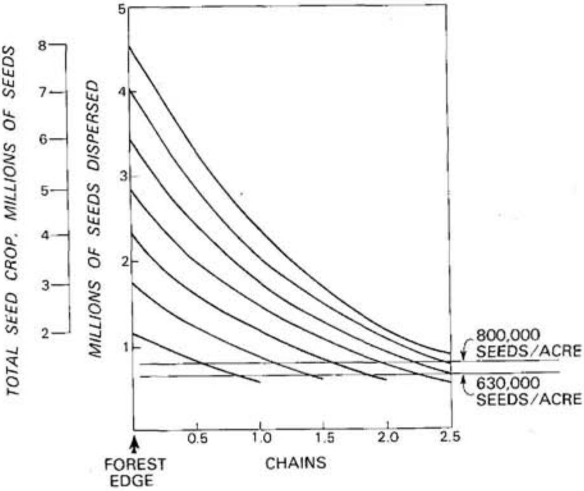


Figure 7. — Distances at which adequate seed is dispersed for seed crops of different size to regenerate a new paper birch stand on undisturbed seedbeds.

topography, and exposure to sunlight and shadow. Guidelines for modifying these influences are given in the Birch Symposium Proceedings *(5)* and in the Silvicultural Guide for Paper Birch in the Northeast *(4)*.

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