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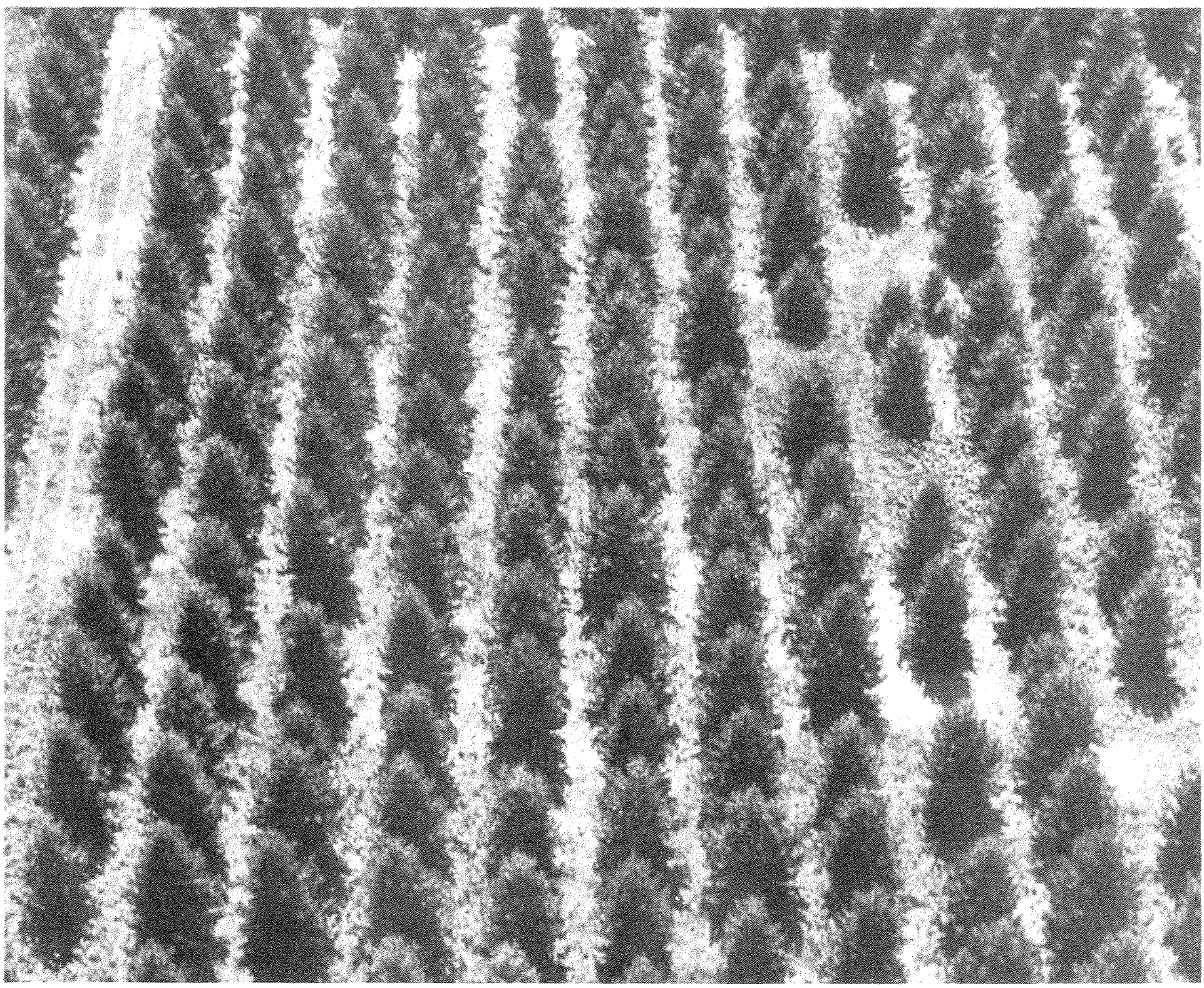

COMPARATIVE CONE PRODUCTION IN YOUNG RED PINE PLANTED AT DIFFERENT SPACINGS

by

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Résumé en français

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ABSTRACT

In 1970 an 18-year-old plantation of red pine (*Pinus resinosa* Ait.), established as a spacing experiment, produced its first heavy cone crop. Cone counts were made on sample trees in each of the 4' x 4', 6' x 6', 8' x 8', 10' x 10', 14' x 14', and 21' x 21' spacings. Dominant height was about 30 feet, and crown closure had taken place at all but the two widest spacings. Attacks by a cone moth (*Dioryctria disclusa* Heinr.) resulted in aborted cones that increased with spacing from nil at 4' x 4' to about 12% of the crop at 21' x 21'. Within a spacing cone crops tended to increase with tree size, and no cones were found on trees of less than the 5-inch-d.b.h. class. The numbers of cones per tree of a given d.b.h. tended to increase with spacing. The numbers per acre also increased up to the widest spacing represented, where about 32,000 mature cones were produced. The relation of crop size to stocking level is represented by the equation $\log Y = 4.6655 - 0.0009796X$, where Y = number of cones per acre, and X = number of trees per acre.

RÉSUMÉ

En 1970, une plantation de pins rouges (*Pinus resinosa* Ait.), agée de 18 ans et originairement établie afin d'étudier l'espacement des arbres, produisit une première grosse récolte de cônes. Ceux-ci furent comptés dans les arbres espacés de 4 x 4, 6 x 6, 8 x 8, 10 x 10, 14 x 14 et 21 x 21 pieds. La hauteur des arbres dominants était 30 pieds et partout le couvert s'était fermé, sauf là où les arbres étaient espacés de 14 x 14 et 21 x 21 pieds. Une chenille des cônes (*Dioryctria disclusa* Heinr.) ne fit avorter à peu près aucun cône des arbres peu espacés, mais à mesure que les arbres devenaient plus espacés, ses dommages augmentèrent (jusqu'à un maximum de 12% chez les arbres espacés de 21 x 21 pieds). En général, plus les arbres étaient grands plus la récolte devenait importante; les arbres de moins de 5 pouces (classe de diamètre) n'en produisaient pas. Le nombre de cônes par arbre appartenant à une classe définie de diamètre était plus élevé si l'espacement était plus large. De même, le nombre de cônes à l'acre augmentait avec l'espacement, et lorsque les arbres étaient écartés de 21 x 21 pieds, l'auteur compta 32000 cônes mûrs. Le rapport entre l'importance de la récolte et la densité du peuplement est représenté par l'équation log Y = 4.6655 - 0.0009796X où Y = nombre de cônes à l'acre et X = nombre d'arbres à l'acre.

INTRODUCTION

Red pine (*Pinus resinosa* Ait.) is an important reforestation species in eastern and central Canada (Anon., 1970), where in 1965, for example, it was used to plant about 12,000 acres (Cayford and Bickerstaff, 1968). While demand for seed is high, good seed crops occur on the average only every 5 years (Anon., 1958), and the yield of seed is often seriously reduced by insect damage to immature cones (Lyons, 1960). Special efforts are therefore directed towards increasing cone production. The establishment of seed orchards and seed production areas to this end capitalizes on the tendency for more open-grown trees to yield heavier cone crops (Anon., 1948). Both Manitoba (Anon., 1970) and Ontario (Anon., 1968) operate stands of this type to help fill their red pine seed requirements.

Precise information on the relation between stocking level and cone yield is of value to the efficient establishment of such stands. An opportunity to obtain information of this kind was presented at the Petawawa Forest Experiment Station in 1970 when a series of 18-year-old red pine plantations established to test spacings of from 4' x 4' to 14' x 14' produced a heavy crop of cones. This was the first appreciable yield of cones by these stands, although a few cones had been produced previously on some trees located in the outside rows.

METHODS AND MATERIALS

Plantations

The plantations were established in 1953 on old-field sites, where soils are deep, fine to medium windblown sands. Trees were planted in separate blocks, each block at one of seven spacings in the range already indicated. In 1965, before the closure of adjacent crowns of trees spaced at 10' x 10', part of this block was thinned systematically to a spacing of 21' x 21'. In each spacing, one or more 1/4- or 1/2-acre permanent sample plots had been established on which periodic measurements were made of stem and crown dimensions.

In 1970 dominant height was about 30 feet at all spacings. The average d.b.h. increased with wider spacing from 2.5 inches at 4' x 4' to 7.9 inches at 21' x 21'. Similarly crown width increased directly with spacing. At 21' x 21' and 14' x 14' trees had full-length crowns, i.e. live branches down to ground level, but at the other spacings the lower branches had died and crown length therefore decreased with denser stocking to about 15 feet in the 4' x 4' plantation.

Sampling

Six plots were selected for cone counts, one each from the 4' x 4', 6' x 6', 8' x 8', 10' x 10', 14' x 14' and 21' x 21' spacings. On each plot the cones were counted, usually on an approximately equal number of sample trees in each 1-inch-d.b.h. class, except the smallest and largest classes, where all trees were included. The sample in each class was distributed as widely as possible over the plot. Sample size varied from 28 to 44 trees on the different plots.

Cone counts were begun on August 31 and ended on September 18. Each sample tree was climbed and examined branch by branch. Cones were listed according to vertical position in the crown (i.e. annual whorl), number in cluster, and whether they were mature and healthy or shrunken and dried without evidence of growth in the current year (i.e. aborted). The sample tree diameters were measured and recorded, and a d.b.h. tally was made of all trees on the plot to obtain the diameter distribution.

A selection of aborted cones was forwarded to the Forest Insect and Disease Survey of the Great Lakes Forest Research Centre, Canadian Forestry Service, at Sault Ste. Marie, Ontario, for identification of the damaging agent.

Compilation and Analysis

Cone counts for each plot were summarized by tree size, and the average number of cones per tree was plotted over the average d.b.h. of the size class. Plot averages for each 1-inch-d.b.h. class were then read off by straight-line interpolation. D.b.h.-class totals were converted to numbers of cones per acre for the whole plot. In these calculations, data for mature cones and for total cones (i.e. mature + aborted) were compiled separately. Finally, a regression equation of total cones per acre on number of trees per acre was derived.

RESULTS

Crown Position

Cones were produced on nearly all live whorls. Thus with wider spacings the cone crop extended farther down the crown. For example, the entire crop at 4' x 4' was contained in the upper (and only living) seven whorls; at 21' x 21' cones occurred down to the 15th whorl (Table 1). (Since red pine cones take 2 years to mature, none were borne on the 1970 whorls.) In most cases more than half the crop was contained in two or three whorls near the center of the live crown. This distribution can be compared with that described by Godman (1962), who found one-half to two-thirds of the cones in the middle third of the living crowns in 51-year-old red pine that had been thinned to residual basal areas of 60 to 140 square feet per acre; by contrast only 9% of cones were found in this zone at 160 square feet of basal area; and few cones occurred in the lowest third at even the least residual density.

TABLE 1. AVERAGE DISTRIBUTION OF MATURE CONES BY BRANCH WHORLS

Annual	4' x 4'		6' x 6'		8' x 8'		10' x 10'		14' x 14'		21' x 21'	
whorl	%	Cum.	%	Cum.	%	Cum.	%	Cum.	%	Cum.	%	Cum.
1970	0	0	0	0	0	0	0	0	0	0	0	0
1969	2	2	3	3	4	4	-[1]	-	-	-	-	-
1968	6	8	8	11	7	11	3	3	1	1	1	1
1967	2	10	16	27	29	40	7	10	2	3	2	3
1966	38	48	29	56	41	81	20	30	7	10	6	9
1965	42	90[2]	26	82	16	97	35	65	19	29	15	24
1964	10	100	18	100	3	100	24	89	21	50	21	45
1963							9	98	23	73	22	67
1962							2	100	16	89	14	81
1961									8	97	10	91
1960									2	99	6	97
1959									-	100	2	99
1958											-	99
1957											-	99
1956											-	100

[1]Dash means less than 1%.
[2]Underlining indicates whorl above which crowns are not touching.

Godman (1962) intimates that flower-bud differentiation is influenced by the currently prevailing environment. Conditions in 1968 (when the cone primordia were differentiated for the 1970 crop of the plantations reported here) varied between spacings mainly with respect to light available to the crowns. Berry (1970), in a separate study in the same plantations, determined the annual whorl level at which adjacent crowns touched in 1969. By subtracting a year in each case, the level of crown closure for 1968 can be estimated, and the corresponding whorls are indicated in Table 1. It can be seen that at spacings where canopies had closed in 1968, virtually the whole cone crop was borne in the "free growing top," or that part of the crown above the level of intertree contact. At wider spacings this level is lower down the tree, and at 14' x 14' and 21' x 21' closure had not yet occurred.

Cone Arrangement

Cones occur singly or in clusters of varying size, in the proportions shown in Table 2. Little effect of tree spacing can be discerned. There was a tendency for more cones to be produced in pairs than in other arrangements. The pairs were followed by triples and then by singles. Clusters of four were relatively rare, and 1% or more of the crop occurred in clusters of five at only the 21' x 21' spacing. Out of the 17,093 cones counted in the study, one sixfold cluster was found.

TABLE 2. PERCENTAGE DISTRIBUTION OF MATURE CONES BY CLUSTER SIZE

Number of cones in cluster	4' x 4'	6' x 6'	8' x 8'	10' x 10'	14' x 14'	21' x 21'
1	23	42	32	27	25	20
2	35	37	43	35	36	32
3	34	19	21	32	32	34
4	8	2	4	6	7	12
5	0	0	0	0	0	2
	100	100	100	100	100	100

Tree Size

Within a spacing, cone crops tended to increase with tree size, thus showing a general relationship observed in a natural stand of red pine at Petawawa on a previous occasion (Horton and Bedell, 1960). The most cones were not found on the largest trees at 14' x 14' and 21' x 21' (Figure 1),

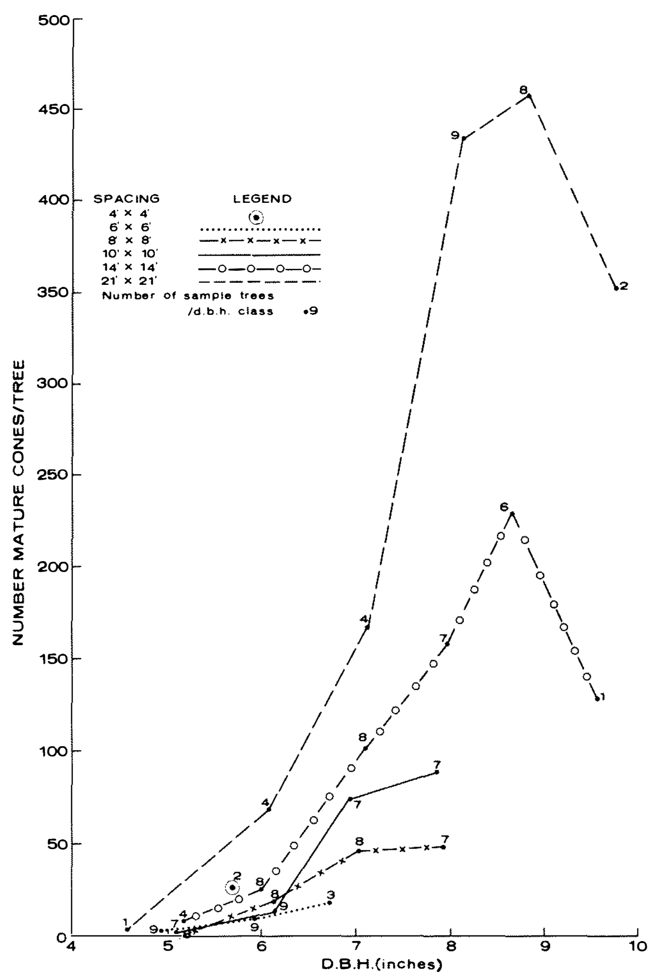

Figure 1. Mature-cone distribution by spacing and tree size.

TABLE 3. AVERAGE NUMBERS OF CONES PER ACRE

D.b.h. class (inches)	4' x 4'	6' x 6'	8' x 8'	10' x 10'	14' x 14'	21' x 21'
1	0	-[1]	-	-	-	-
2	0	0	0	0	-	-
3	0	0	0	0	0	-
4	0	0	0	0	-	-
5	0	2,028	172	126	66	39
6	208	1,617	5,078	1,587	728	738
7	-	220	4,687	12,684	6,644	2,490
8	-	-	382	3,157	12,818	17,092
9	-	-	-	-	2,635	11,238
10	-	-	-	-	256	707
Total mature	208	3,865	10,319	17,554	23,147	32,304
Total cones (mature + aborted)	208	3,948	11,192	19,473	25,383	37,842
Average number of cone-bearing trees per acre	8	732	548	388	200	95
Sample size, number of trees	30	34	44	34	35	28

[1]Dash means no trees on plot in that diameter class.

but this may have been due to the smallness of the sample available in these sizes. Variability was high within size classes. For example, the range in crop size for trees of the 8-inch-d.b.h. class at 21' x 21' was from 163 to 1,025 mature cones; the latter was the largest crop found on an individual tree. No cones were found at any spacing on trees of less than the 5-inch-d.b.h. class (Table 3).

Damage

The cause of aborted cones was identified as the rusty pine cone moth (*Dioryctria disclusa* Heinr.). The average intensity of damage by spacing, shown in Table 4, increased from nil at 4' x 4' to about 12% at 21' x 21'. The highest damage rate found on a single tree was 29% of the cones aborted. The pattern of attack is consistent with the behavior described by Lyons (1960), wherein the heaviest damage occurs on large-crowned open-grown trees, although the potential intensity (seed reduction of 40 to 100%) cited by him was not approached.

TABLE 4. PROPORTION OF MATURE CONES TO TOTAL CONES IN SAMPLE

Spacing (feet)	Total cones	Mature cones	
		Number	% of total
4 x 4	52	52	100.0
6 x 6	175	170	97.1
8 x 8	916	856	93.4
10 x 10	1,423	1,277	89.7
14 x 14	4,042	3,660	90.5
21 x 21	10,485	9,244	88.2
	17,093	15,259	89.3

Spacing

More cones per tree of a given d.b.h. class were found at wider spacings for all except the smallest sizes of cone-bearing trees and the single tree found bearing cones at 4' x 4' (Figure 1). Similarly, cone production per acre increased up to the widest spacing represented (Table 3). The relation of crop size to spacing (expressed as trees per acre) gives a straight line on semilog paper, for which the equation is:

$$\log Y = 4.6655 - 0.0009796X \qquad (r^2 = 0.995),$$

where Y = number of cones per acre and X = number of trees per acre (Figure 2). These values are for total production, not mature cones only.

DISCUSSION

A puzzling feature of this study is the larger cone crop found at 21' x 21' than at 14' x 14'. In 1968, when the cone primordia were laid down, trees at both spacings were fully open grown, at least in that there was no lateral contact between crowns and all whorls were alive down to ground level. Yet the superiority of the crop at 21' x 21' is very marked for all d.b.h. classes (Figure 1). Heavy thinning in closed stands has been reported to stimulate cone production in red pine (Cooley, 1970; Godman, 1962), but thinning effect is not thought to account for the heavy crop at 21' x 21' since adjacent crowns had not closed when the stand was reduced from 10' x 10' in 1965. It appears that spacing effects on cone production involve more than providing sufficient light merely to sustain a full-length crown. This is probably related to the fact that stem and crown diameters, even in the "free growing top" of red pine and not merely at or below the level of crown closure, are reduced at higher stand densities (Berry, 1970).

It is unfortunate that even wider spacings were not represented in this study, since the stocking level at which stands of this particular

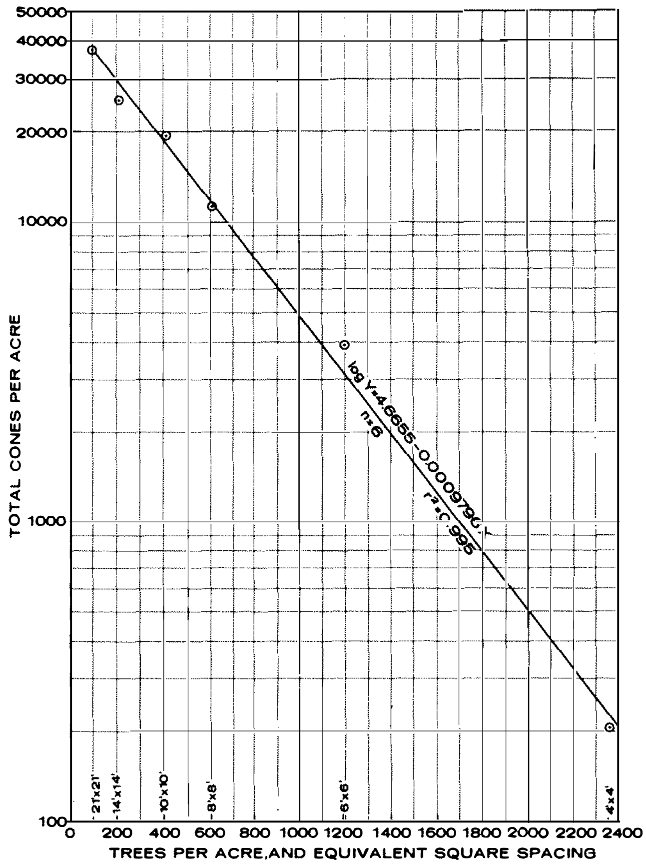

Figure 2. Relation of total cones per acre to spacing and equivalent numbers of trees per acre.

height class would achieve maximum cone production was not demonstrated. It is presumed that at some point increasing numbers of cones per tree would be offset by decreasing numbers of trees per acre as was found with some other species of pine (Graber, 1970; Florence and McWilliam, 1956). The curve in Figure 2 cannot be extrapolated very far to the left, as it must obviously fall rapidly to 0 cones per acre for 0 trees per acre. It appears, therefore, that 40,000 cones per acre could be taken as about the limit of total production for this particular series if insect damage had been controlled. While the actual crop values found could not be expected to be invariable under similar stand and site conditions, the interspacing relationship should hold.

Planting red pine at 21' x 21' should give close to maximum cone production at the time of the first heavy crop. Other advantages of this spacing are that the entire crop is borne on less than 100 trees per acre and that every tree is fully accessible on all sides (about 7 feet separated adjacent crowns in 1970), factors that should facilitate cone collection. On the other hand, some trees may be of poor form and some may not bear many cones. This study showed that cone production varied widely between otherwise similar trees, and red pine is described as characteristically comprising both trees that are consistently good cone producers and those that are consistently poor producers (Fowells, 1965, p. 435). Initial spacings cannot be maintained indefinitely and, as the stand grows taller, the number of trees must be reduced to allow continued expansion of the crowns (Wright and Bull, 1963). The opportunity exists in early thinnings, then, to remove trees of inferior phenotype and those which are demonstrated to be poor cone producers.

To ensure optimum production over the cone-bearing life of the plantation, therefore, it may be preferable to sacrifice some of the high potential yield of the first crop by planting at closer spacings than 21' x 21' and thereby permitting latitude in selection when thinning becomes necessary.

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