A Comparison Among Four Commonly Used Soil Fumigation Techniques in a Wisconsin Bareroot Seedling Nursery

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Abstract

In 2016, the Wisconsin Department of Natural Resources initiated a study comparing several soil fumigant options in a side-by-side trial at the Wilson State Nursery. A 77:33 ratio of methyl bromide/chloropicrin (MBC33) was the operational treatment, as this was the soil fumigant historically used at Wilson Nursery with consistent success. The alternatives tested were metam sodium, 100-percent chloropicrin, and a no fumigation control. Three replicates of each treatment were sown with jack pine (*Pinus banksiana* Lamb.), red pine (*P. resinosa* Aiton), white pine (*P. strobus* L.), and white oak (*Quercus alba* L.). Germination was evaluated weekly in each treatment plot. At lifting, seedlings were measured for height, stem diameter, shoot dry mass, and root dry mass. In addition, weed mass was measured in each plot. Germination was relatively poor in all plots due to erratic weather conditions that season. Weed biomass was least in methyl bromide plots. Seedlings were largest in chloropicrin and methyl bromide plots. This paper was presented at the 2019 Joint Annual Meeting of the Northeast and Southern Forest Conservation Nursery Associations (Atlantic City, NJ, July 23–25, 2019).

Background

Wisconsin Department of Natural Resources' bareroot seedling nurseries have long depended on soil sterilization via fumigation as a necessary first step in preparing ground for planting. Over the years, many products have been tried with varying success, but the standard treatment for Wisconsin became a shank-injected and tarped application of methyl bromide and chloropicrin (MBC33). However, due to environmental concerns regarding methyl bromide and ozone depletion, the nurseries came under increasing political pressure to find an alternative.

Metam sodium is commonly used in Central Wisconsin to sterilize potato and vegetable fields. This fumigant is shank-injected and water sealed, rather than tarped, and has overall fewer environmental concerns. Because of its proven history in vegetable production in Wisconsin, metam sodium seemed like an effective and low-cost alternative to methyl bromide for the State nurseries, and the switch was made in 2013. After a couple of years of metam sodium use, however, Wilson State Nursery (Boscobel, WI) observed conifer stunting and increasingly frequent problems with root rots in various species. Additionally, delayed germination and poor bed densities were noted since switching fumigants. While no clear cause and effect could be drawn, the problems were troubling enough to justify a return to MBC33, and to establish a trial to compare the efficacy and phytotoxicity among fumigation alternatives.

Methodology

Four fumigation treatments were randomly assigned locations in each of three replications in the bareroot field at Wilson State Nursery by dividing each block into four plots, writing treatments on cards, shuffling, and drawing a treatment card for each plot. The same card-draw method was used within each treatment to randomly assign species locations (figure 1). The four treatments were: 100-percent chloropicrin (CP), metam sodium (MS), 77:33 methyl bromide + chloropicrin (MB), and a nonfumigated control (NONE). Metam sodium was applied at 75 gal/ac (700 L/ha) on August 15, 2016 (figure 2).

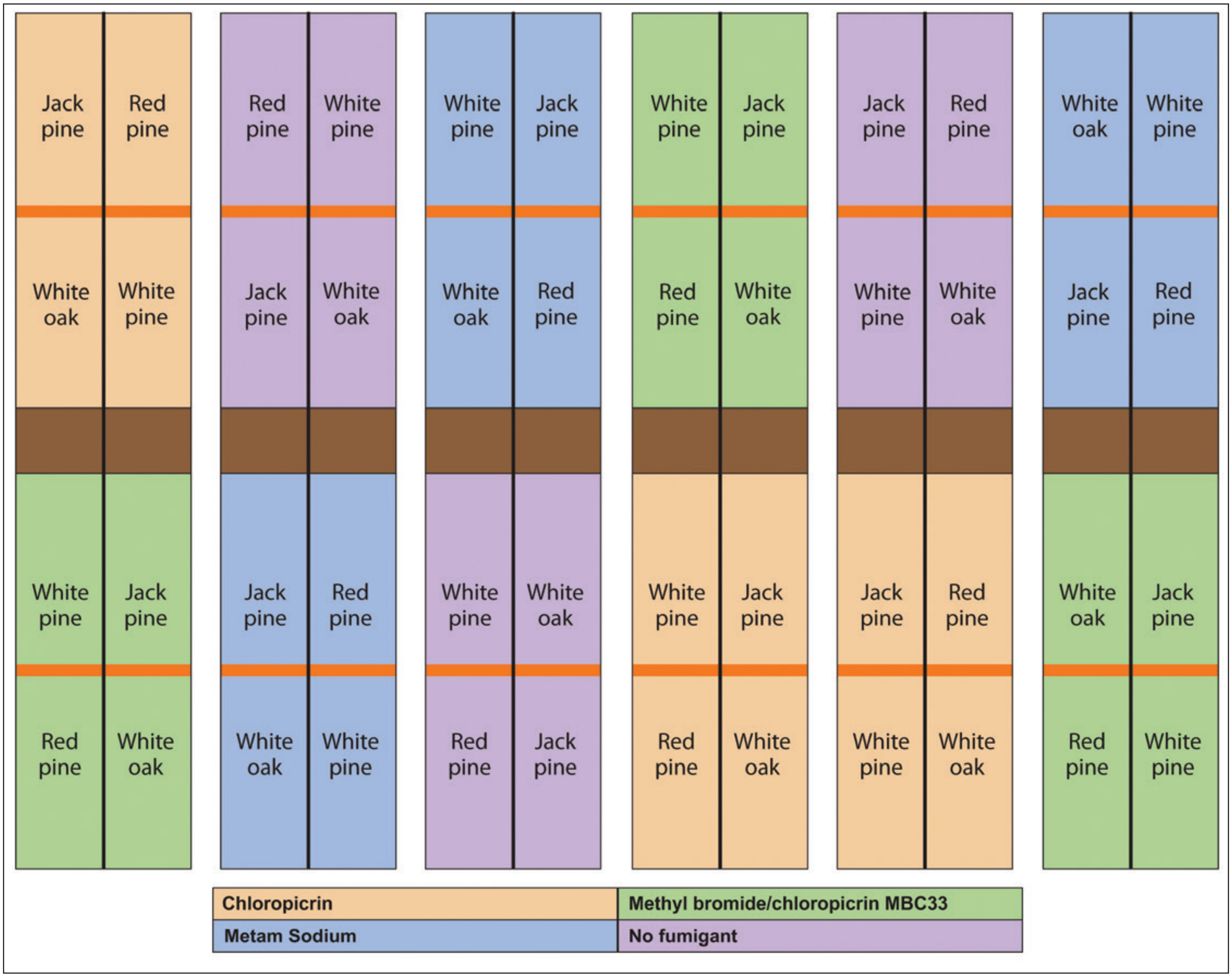

Figure 1. Randomly assigned spatial distribution of trial plots in nursery beds at the Wilson State Nursery to evaluate four fumigation treatments on four species.

Chloropicrin 100 and methyl bromide-chloropicrin (MBC33) were applied on September 17, 2016, both at 240 lbs/ac (270 kg/ha). A two-bed buffer (12 ft [3.7 m]) was established between all treatments to reduce edge effects.

The four species included in the study were: jack pine (*Pinus banksiana* Lamb.), red pine (*P. resinosa* Aiton), white pine (*P. strobus* L.), and white oak (*Quercus alba* L.). Seed for all species was sown October 20–24, 2016. Each species/treatment plot was approximately 120 ft by 4 ft (36.6 by 1.2 m). All plots were treated regularly, at approximately 5-week intervals, with pre-emergent herbicides (oxyflourfen and pendimethelin), at the same time as the rest of the nursery's production pine beds. The fungicide mefenoxam was applied to all conifer beds at the beginning of germination as a precaution against damping off, and prophylactic applications of thiophanate methyl, mancozeb, and chlorothalonil were applied according to the nursery's regular fungicide spraying schedule to prevent various shoot and foliar diseases. All stock was irrigated as needed, as determined by nursery staff.

Three seedling-sampling grids, each 6 by 48 in (15.2 by 121.9 cm), were established in each species/treatment plot, roughly 25 ft (7.6 m) apart from each other. These grids were inventoried weekly to monitor germination, survival, and growth. In addition, 2 by 4 ft (0.6 by 1.2 m) weed-sampling grids were established in each plot to measure weed development. To assess weed-control efficacy, weed mass in each grid was evaluated on July 20 of the first growing season

Figure 2. Metam sodium application rig. (Photo by Kyoko Scanlon 2016, Wisconsin Department of Natural Resources)

by removing all weeds at the ground line, then drying and weighing them.

Jack pine and white oak seedlings were harvested in April 2018 as 1-0 seedlings using standard nursery lifting techniques. Twenty jack pine seedlings from each of three replications (seedbeds) were measured. No data were collected from the white oak, as the population was too low to get valid data. Red pine and white pine (60 seedlings per replication) were harvested the following spring (April 2019) as 2-0 seedlings. At lifting, pine seedlings of each species were measured for height from root collar to terminal bud, and for stem diameter just above the root collar. Seedlings were then thoroughly washed, roots were severed at the root collar, and both shoot and root dry weights were measured using standard lab procedures.

Results

Bed Density

One of the concerns with metam sodium, based on anecdotal evidence, is the possibility of delayed germination and low bed densities. Unfortunately, we were unable to evaluate this adequately due to low bed densities across all trial plots in spring 2017. Our target seedling density for conifer beds is 31 trees/ft2 (335 trees/m^2). Actual densities across the various treatments in 2017 were less than 10 trees/ft^2 (less than 110 trees/m^2). In fact, Wilson Nursery had very poor germination in nearly all fall-planted seed beds in 2017, with total failures in several species, presumably due to the erratic winter weather.

Although germination was poor for all treatments, red pine germination was statistically significantly lower in the chloropicrin plots (figure 3). There was a similar, but not statistically significant, decrease in white pine germination in chloropicrin plots (data not shown). Interestingly, however, the nursery's saleable inventory sampling conducted in August showed the chloropicrin plots produced fewer cull seedlings, so the final saleable yield was comparable with the other treatments, despite lower germination (table 1). This lower germination on chloropicrin treated ground is concerning, but it is a problem that should be easy to correct by increasing seeding rates.

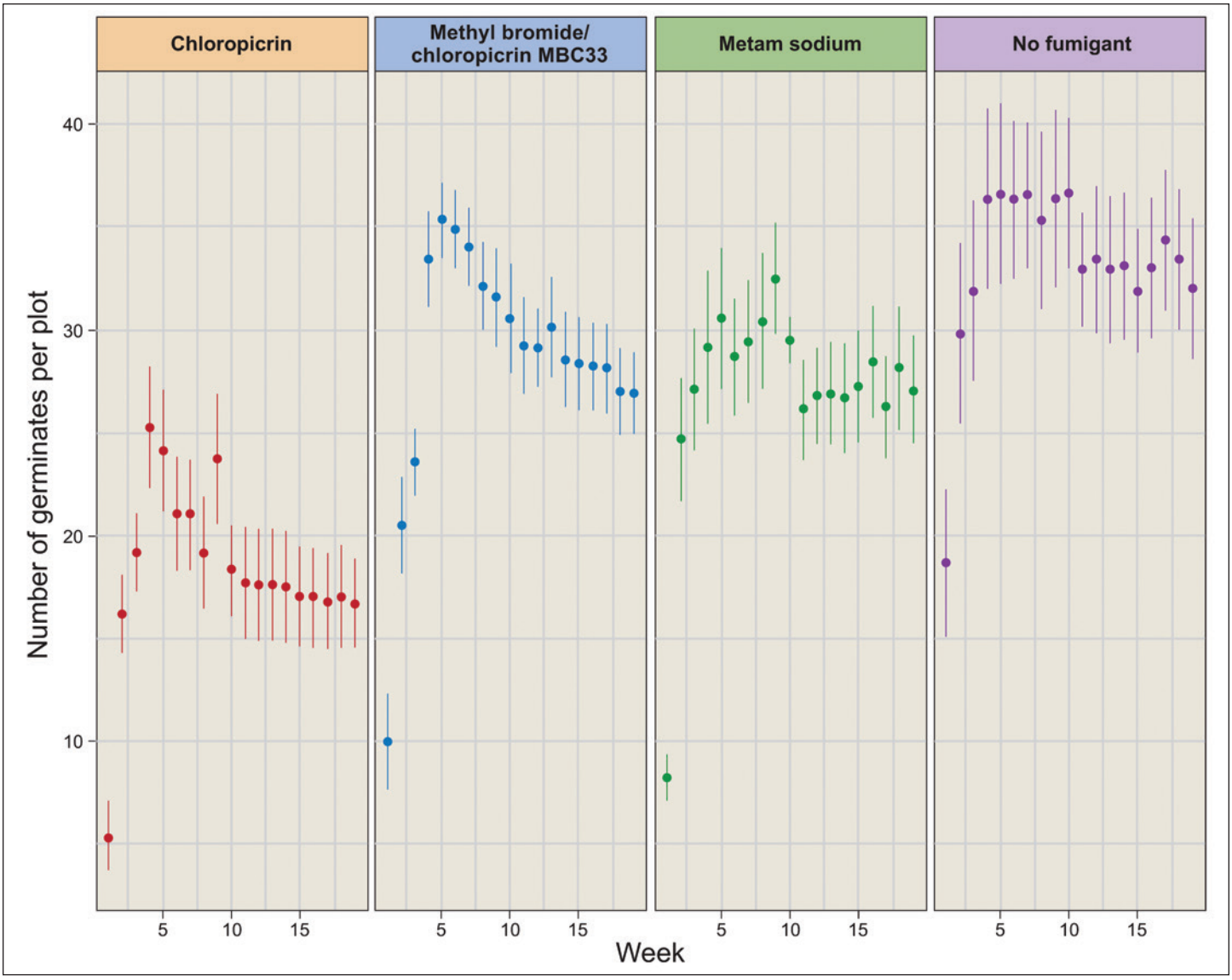

Figure 3. Red pine bed density was lowest in chloropicrin plots.

Weed Biomass

White oak seedbeds require a layer of chopped straw mulch, which introduced a considerable amount of weed seed, primarily hawksbeard (*Crepis* spp.) and groundsel (*Senecio vulgaris* L.) into the fumigated study area. Thus, the mulch likely increased the overall weed biomass across all plots. However, all blocks should have been affected to the same degree.

As expected, methyl bromide provided the best weed control, although all three fumigant treatments had significantly less weed biomass than the unfumigated treatment (figure 4). This differential between fumigated and unfumigated plots would likely have been even greater without the addition of the chopped straw in the white oak plots.

Seedling Morphology

Seedlings grown in the chloropicrin plots were largest for all three pine species (figure 5). Those grown in the methyl bromide plots were also consistently larger than those in the nonfumigated plots. Jack pine seedlings performed quite well on metam sodium (figure 5), which was unexpected based on previous anecdotal observations at Wilson State Nursery. On the other hand, white pine seedlings grown in metam sodium plots tended to be smaller than all other treatments, including the nonfumigated control. White pine stunting was an issue the nursery struggled with previously while using metam sodium operationally and was one of the main reasons for discontinuing its use. Height and stem diameter results among treatments for each species were similar to the biomass results (data not shown).

Table 1. Estimated cull seedling percentages during August sale inventory for each species/treatment.

Treatment	Average trees/ft²	Field cull (%)	Saleable trees/ft²
Jack pine			
Chloropicrin	11.3	7.1	10.5
Methyl bromide + chloropicrin	10.2	17.1	8.5
Metam sodium	11.3	14.0	9.7
Control (untreated)	10.6	41.6	6.2
Red pine			
Chloropicrin	11.7	23.5	8.9
Methyl bromide + chloropicrin	13.1	30.3	9.1
Metam sodium	13.2	30.6	9.2
Control (untreated)	13.4	54.1	6.2
White pine			
Chloropicrin	12.0	39.3	7.3
Methyl bromide + chloropicrin	14.1	42.1	8.1
Metam sodium	13.4	66.2	4.5
Control (untreated)	12.8	50.4	6.3

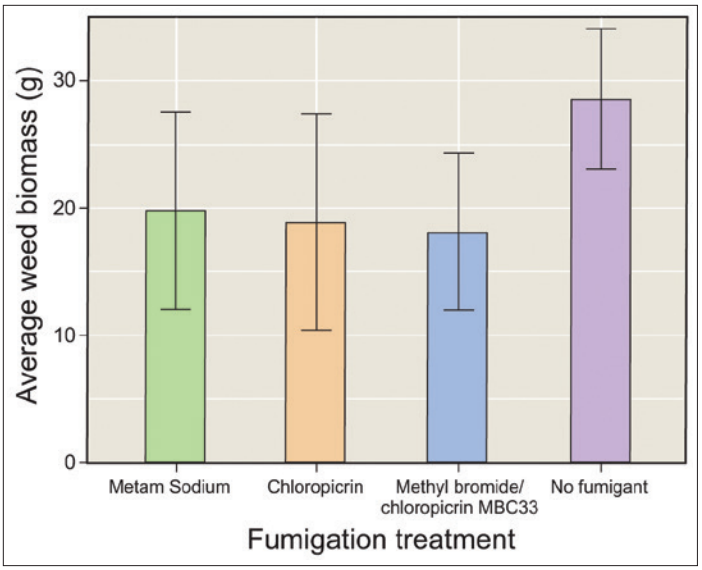

Figure 4. Weed biomass (July 20, 2017) was highest in untreated plots.

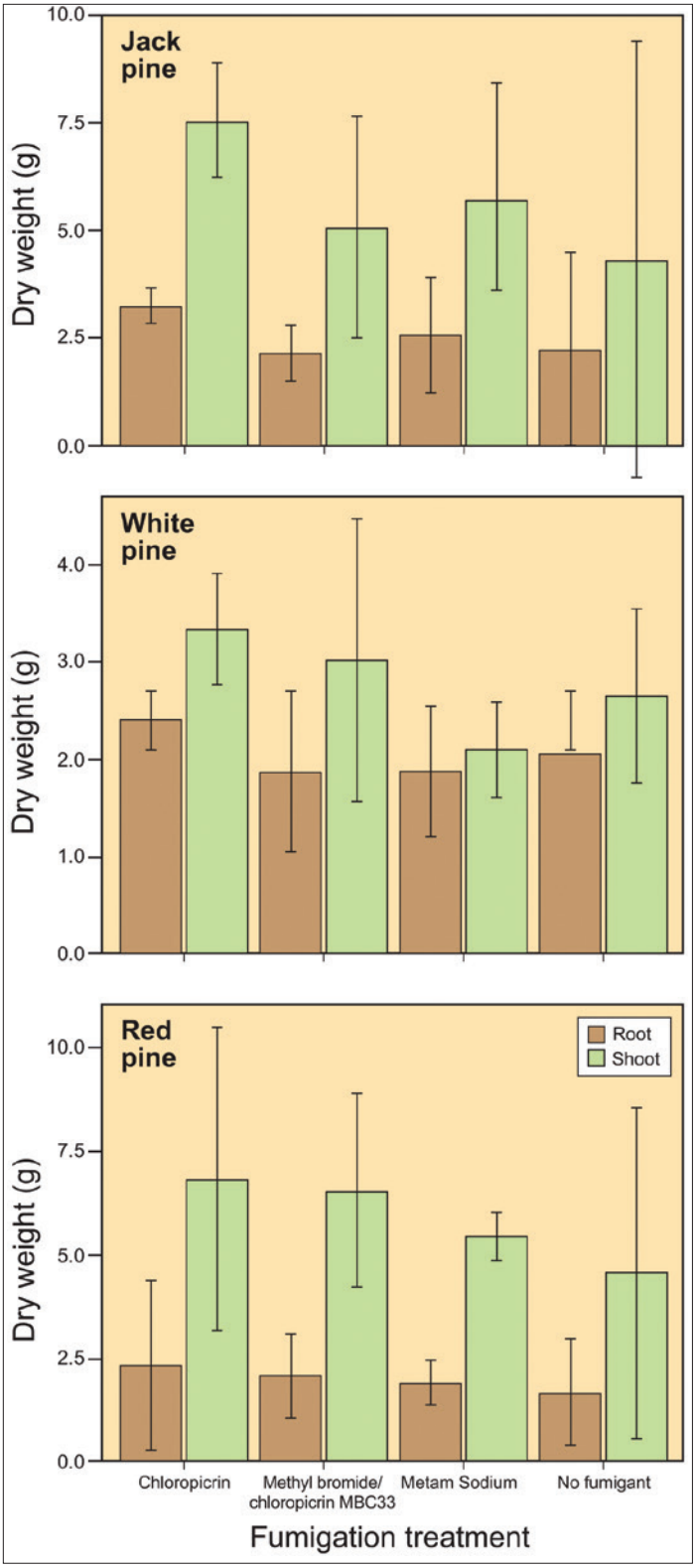

Figure 5. Shoot and root biomass varied among fumigation treatments for three pine species.

Management Implications

This trial did not give clear answers to all of the nursery's fumigation questions. It did, however, yield some information that will prove useful in making future management decisions. While MBC33 did not consistently outperform the other fumigants, it produced solid results on all species, and provided good weed control. This, along with the long history of successful MBC33 use in Wisconsin nurseries, makes it the preferred fumigation option. Chloropicrin's solid performance on all species show that it is a viable alternative should methyl bromide be unavailable, but the poor germination shown would need to be compensated for with higher seeding rates. The comparatively poor growth of all species grown under the no fumigation treatment confirms that this approach is not a viable option for our operation, which strives to consistently produce 5- to 8-inch (13- to 20-cm) jack pine seedlings in one growing season, and similar sized red pine and white pine in two growing seasons.

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