levels of TSS and NO_3-N present in the bed indicate that the intermittent irrigation treatment resulted in accumulating one-third more TSS than the continuous type. Nitrogen applications increased the TSS in the top 5 cm but had no effect on TSS at the other sampling levels. Intermittent irrigation also increased the NO_3-N found in the beds at the last sampling date. Without added N, the intermittent irrigation resulted in 22% more NO_3-N in the bed and 62% more NO_3-N when N was added. Most of the increase in NO_3-N was found in the top 5 cm, particularly in the center of the beds. Nitrogen applications increased the NO_3-N by 102% with continuous irrigation and 168% with intermittent irrigation. Of this increase, 96% was found in the top 5 cm of beds irrigated continuously and 85% when irrigated intermittently. Without the addition of N, the NO_3-N in the beds at the third sampling date showed that 50% and 45% of the amount found in the first sampling was leached below the sampling zone by continuous and intermittent irrigation, respectively. When N was added, 21% of the NO_3-N originally present was leached by continuous irrigation, whereas with the intermittent irrigation there was a 13% increase in NO_3-N. The additional NO_3-N added to the beds, plus that resulting from nitrification of the added NH_4-N, likely influenced this difference in the amounts leached.

Conclusions

While certain treatments resulted in more NO_3-N in the beds than others, most of it was concentrated in the center of the top 5 cm. Regardless of treatment there was little difference in NO_3-N concn in the area where the roots of the small lettuce plants usually grow. In this area the uniformly low concn would indicate that N applications ahead of listing would be ineffective with the types of germination irrigations used in these studies. The low NO_3-N concn found in the root zone where young lettuce plants usually grow accounts, in part, for the N deficiencies often observed in young lettuce plants, despite preplant N applications. The NO_3-N in the center of the beds where the greatest amount is located would not be available to or utilized by the plant until the plant root system is large enough to occupy this area. Further, only a small amount of this N would be available for use unless a rain moves it from the surface depths down into more of the root zone. Since these data indicate that preplant applications of N would be ineffective for lettuce seedling growth, early sidedress applications are usually necessary to insure appropriate early development.

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The Potential Use of Antitranspirants in the Greenhouse Production of Chrysanthemum[1]

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Abstract. **Three film-forming antitranspirants were applied to potted chrysanthemums (*Chrysanthemum morifolium* Ramat.) under greenhouse conditions from the time of potting rooted cuttings to saleable size. Folicote (a hydrocarbon wax emulsion of essentially fully refined paraffin) reduced water loss by an average of 39% and by as much as 65%, but generally detracted from plant appearance, delayed flowering, depressed fresh and dry weight, decreased flower size, increased height and reduced leaf area. While Clear Spray (a lateral based emulsion of undefined composition) and Wilt Pruf NCF (whose active ingredient is a polyterpene compound, Pinolene) reduced water loss 8 and 11% respectively, their side effects were less deleterious and, in a few cases, beneficial. Effects of antitranspirants under summer greenhouse conditions appeared to be of a greater magnitude than during a cooler season of the year.**

Because of limited soil volumes, plants in pots are susceptible to moisture stress during their production, particularly following transplanting and during hot summer conditions. Small pots pose even greater watering problems and they do not readily lend themselves to most automatic watering systems. It was thought that suitable film-forming antitranspirants, applied during production of potted crops, might alleviate watering problems.

Much of our knowledge of plant antitranspirants has been summarized by several authors (5, 6, 9, 12, 14). Various latexes, plastics, resins, silicones, and waxes have been studied for antitranspirant properties. A number of these have substantially reduced transpiration but often with side-effects, many of which are undesirable. This research was initiated to study the long-term effects of repeated antitranspirant application on plant production.

Materials and Methods

The study consisted of 2 tests, one conducted during an

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approximate 9-week period beginning in June (warm season) and the other during a period of similar length beginning in Dec. (cool season) under prevailing greenhouse conditions. Tip cuttings (7.4 cm) of 'Matador' chrysanthemum were rooted and potted in 10 cm. (4 inch) square plastic pots equipped with a glass and asbestos wick inserted through one of the drainage holes. Pots were sealed in plastic bags and snugly fit into deeper plastic containers which held a water and/or fertilizer reservoir. Wicks extending through the bags drew from the water supply as dictated by plant requirements. In this manner, pots had adequate moisture.

Plants were initially grown under long-day conditions for 1 week prior to the initiation of short days. During this long-day period, height was measured and an initial leaf area total was determined using a modified procedure of Cocking and Tukey (3). Initial values for transpirational water loss were made gravimetrically using the total leaf areas, and water loss determined on a leaf area basis with 148 plants exhibiting the most uniform transpiration being selected for treatment. After this initial selection, 4 plants each were chosen at random to receive 1 of the 36 treatments.

Three film-forming antitranspirants chosen on the basis of earlier trials were Clear Spray (W. A. Cleary Corp., New Brunswick, N. J.), Folicot (Sun Oil Co., Sunoco Division, Marcus Hook, Pa.), and Wilt Pruf NCF (Nursery Specialty Products Division of J. A. Hartman Corp., Greenwich, Conn.). Antitranspirants were applied using a hand held vibrator-type paint sprayer in one of 3 concn (high, medium and low). Antitranspirant concn were as follows: Clear Spray (20%, 10%, 5%); Folicot (10%, 5%, 2.5%); Wilt Pruf NCF (20%, 10%, 5%). Spray material was applied to all exposed plant parts to run off. The 3 antitranspirants, at each of their 3 levels, were applied either 1, 2, 3 or 4 times at 2 week intervals. Four untreated plants per test served as controls.

The experiment was analyzed as a randomized complete block design, the 2 tests being treated as blocks. Data were analyzed in the form of difference from control.

Seven variables were measured: leaf area increase, height increase, fresh wt, dry wt, number of days for flowering, floral diam, and total transpirational water loss on a leaf area basis. Transpiration determinations in the 2 tests were made gravimetrically. Plants were weighed every 2 days for 8 weeks of study. Loss of weight was regarded as transpiration and was expressed as g of water lost per cm^2 of leaf area for the 8 weeks beginning at the start of short days.

Three leaf area totals were made, one initially, one after 3 weeks and one at the end of the study. Means between the 1st and 2nd areas and 2nd and final areas were also used to increase the number of total leaf areas to 5. The difference between the initial and final leaf area totals was considered the increase in leaf area.

The number of days for flowering was measured from the start of short days until the first petal rows of flowers opened away from the floral center to form approximately a 180^{o} angle. Floral diam was measured at this time as was final height and fresh wt. The difference in height from the initial to the final measurement was considered the height increase. After other measurements were taken, plants were clipped at the soil line and fresh wt determinations made, and then oven dried to obtain dry wt.

Greenhouse conditions varied greatly during both tests of this experiment. Day temp averaged 31 ± 6.2°C (88 ± 11.1°F) and night temp averaged 18 ± 2.2°C (65 ± 3.0°F) in the warm season test. In the cool season test, day temp averaged 24 ± 5.7°C (75 ± 10.3°F) and night temp averaged 16 ± 0.8°C (60 ± 1.4°F).

Results

Water loss. Treatment with any of the 3 antitranspirants studied reduced water loss of 'Matador' chrysanthemum (Table 1). Overall, reductions in the transipirational water loss of 8, 39, and 11% were recorded for the products Clear Spray, Folicote, and Wilt Pruf NCF, respectively. Folicote has the most significant effect, lowering water loss by an average 2 g/cm^2 per 8 weeks. Folicote was significantly superior to the other 2 antitranspirants in both the 1st and 2nd tests, although its effect was of less magnitude in the 2nd test. Wilt Pruf NCF tended to be slightly more effective than Clear Spray in reducing transpiration.

As the number of applications of antitranspirant was increased, the transpiration of plants was reduced (Table 1). In combined data, 1 application of Folicote significantly reduced water loss over controls, while it required 3 applications of Clear Spray and 2 applications of Wilt Pruf NCF to get a significant reduction over the control (Table 1).

There was a tendency towards a progressive reduction in transpiration as antitranspirant concn was increased. And as the concn was increased in conjunction with an increase in the number of applications, water loss was progressively reduced. Folicote was the most significant in this respect. Concn data are not presented in tables.

Appearance. In both tests, while Clear Spray and Wilt Pruf NCF exercised a slight effect on flowering, plants treated with these compounds were similar in vigor, general appearance, and quality as controls, except that some exhibited slightly glossier foliage (data not shown). Plants treated with Folicote, and in particular those administered higher concn and/or multi-applications, were of less vigor than controls, often being lighter green. The degradation of quality associated with Folicote was more acute under warmer summer conditions.

About 4 weeks into the first test, for 3 consecutive days, temp highs in the greenhouse registered above 38°C (100°F). Plants treated with a multiple application of Folicote at a 5% concn or higher developed bronzed or browned areas on the upper surfaces of leaves. The other 2 antitranspirants at even their highest rate showed no such injury, nor did the control plants. In the cooler winter period, no like injury occurred.

Days until flowering. Folicote has the most significant effect on flowering, delaying it an average 3.8 days. Clear Spray slightly delayed flowering while Wilt Pruf NCF hastened it but neither did so significantly (Table 2).

Under the warm conditions of test 1, an average of 3.9 days longer was required for Folicote treated plants to flower and in test 2, the cooler period, Folicote treated plants flowered an average 3.7 days later. Flowers of some plants receiving multiple applications of Folicote at higher concn in warm temp never fully developed.

Only Folicote significantly delayed flowering as applications were increased (Table 2). In test 1, as the number of applications of Folicote was increased from 1 to 4, the time required for flowering became increasingly longer. Plants treated with

Table 1. Mean effects of biweekly applications of antitranspirants Clear Spray, Folicote, and Wilt Pruf NCF on transpirational water loss of 'Matador' chrysanthemum (Test 1-2).

Treatment[y]	Difference in water loss from control[z] (g/cm^2 per 8 wk)				
	1 Applic	2 Applic	3 Applic	4 Applic	Mean
Clear Spray	−0.12fg[x]	−0.213ef	−0.55cde	−0.70cd	−0.40b[x]
Folicote	−0.88c	−1.68b	−2.66a	−2.90	−2.03a
Wilt Pruf NCF	−0.23efg	−0.44def	−0.71cd	−0.86c	−0.56b
Control	0.00g	0.00g	0.00g	0.00g	0.00c
Mean	−0.48c[x]	−0.78b	−1.31a	−1.49a	

[z]Mean control water loss was 5.15 g/cm^2 per 8 wk.

[y]Includes all 3 rates of each chemical.

[x]Mean separation by Duncan's multiple range test, 5% level.

Table 2. Mean effects of biweekly applications of antitranspirants Clear Spray, Folicote, and Wilt Pruf NCF on days until flowering of 'Matador' chrysanthemum (Test 1-2).

Treatment[y]	Difference in days until flowering from control[z] (days)				
	1 Applic	2 Applic	3 Applic	4 Applic	Mean
Clear Spray	+0.15d[x]	+0.17d	+0.39d	+0.77cd	+0.37b[x]
Folicote	+0.91cd	+2.10c	+4.62b	+7.55a	+3.80a
Wilt Pruf NCF	−0.04	−0.23d	−0.19d	−0.62d	−0.27b
Control	0.00d	0.00d	0.00d	0.00d	0.00b
Mean	+0.34c[x]	+0.68c	+1.61b	+2.56a	

[z]Mean control days until flowering was 58.88 days.
[y]Includes all 3 rates of each chemical.
[x]Mean separation by Duncan's multiple range test, 5% level.

Table 4. Mean effects of biweekly applications of antitranspirants Clear Spray, Folicote, and Wilt Pruf NCF on floral diam of 'Matador' chrysanthemum (Test 1-2).

Treatment[y]	Difference in floral diam from control[z] (cm)				
	1 Applic	2 Applic	3 Applic	4 Applic	Mean
Clear Spray	+0.12cd[x]	+0.07cd	+0.003cd	−0.07cd	+0.03b[x]
Folicote	+0.02cd	−0.32c	−1.24b	−3.69a	−1.31a
Wilt Pruf NCF	−0.02cd	+0.10cd	+0.40d	+0.20cd	+0.17b
Control	0.00cd	0.00cd	0.00cd	0.00cd	0.00b
Mean	+0.04c[x]	−0.05bc	−0.28b	−1.18a	

[z]Mean control floral diam was 12.09 cm.
[y]Includes all 3 rates of each chemical.
[x]Mean separation by Duncan's multiple range test, 5% level.

4 applications of Folicote in this test required an average 8.7 days longer to flower than control plants. While only being significant in the case of Folicote, as concn of an antitranspirant was increased, delay in flowering also increased. Folicote at a 10% concn, increased the time required for flowering by 5.0 days as compared to an increase of 2.5 days for plants treated with 2.5%.

As concn and number of applications were increased, days required for flowering were increased; however, only Folicote was significant in this respect. A delay of 10.4 days was recorded with 4 applications of 10% Folicote but only a day delay occurred with one application of 2.5% Folicote.

Dry wt. Clear Spray and Wilt Pruf NCF increased dry wt over that of controls an average 0.54 g and 0.40 g, respectively, with Folicote depressing dry wt 1.16 g (Table 3). This is an average 22% reduction in dry wt for Folicote-treated plants.

Effects of treatments on dry wt were similar in both tests, differences being ones of magnitude rather than direction of response. As the number of applications was increased, dry wt of treated plants was reduced (Table 3). Four applications were more deleterious than either 1 or 2 applications.

As Folicote concn increased, with an increase in the number of applications, dry wt was progressively decreased. In the first test, treatment with 4 applications of 5 or 10% Folicote resulted in weak, non-vigorous grown with 4 applications of 10% Folicote reducing dry wt an average 3.18 g.

Floral diam. While Clear Spray and Wilt Pruf NCF tended to slightly increase floral diam, Folicote had the only real effect, reducing it an average 1.3 cm or 11% (Table 4).

As the concn of Folicote was increased, floral diam was reduced, with differences in concn of the other 2 antitranspirants being non-significant.

As the concn of Folicote was increased in conjunction with an increase in the number of applications, floral diam was reduced. In the first test, Folicote had the most dramatic effect, with 1 application of 2.5% Folicote yielding flowers averaging 12.1 cm, but 4 applications of the 10% concn resulted in flowers with diam 8.6 cm less than controls; an average diam of 3.8 cm.

Fresh wt. In the combined test data, Clear Spray and Wilt Pruf NCF had no significant effect on fresh wt of 'Matador', though there was a slight increase with their use. Folicote exhibited a significant effect on fresh wt, reducing it by an average 4.1 g, an 8% reduction in fresh wt (Table 5).

Height increase. Plants treated with any of the 3 antitranspirants were, on the average, taller than controls (Table 6). Folicote was the most significant in this effect, increasing height of 'Matador' at the time of flowering by 1.6 cm. As the number of applications was increased, the height of plants generally increased (Table 6). While with each additional application height became greater, the only statistical significance was the difference between 1 and 4 applications. While all antitranspirants generally increased height, only Folicote did so significantly as it was reapplied (Table 6) with 4 applications of Folicote resulting in taller plants than 1 or 2 applications.

Leaf area increase. None of the antitranspirants tested had a significant effect on leaf area of 'Matador'. However, considering combined data, Clear Spray and Wilt Pruf NCF tended to increase leaf area with Folicote tending to reduce it. Data in both tests were very inconsistent.

Discussion and Conclusions

Our results suggest that film-forming antitranspirants can significantly reduce the water use of potted chrysanthemum in the course of greenhouse production but may, in doing this, disrupt to varying degrees other plant processes and plant saleability.

Clear Spray, Folicote, and Wilt Pruf NCF reduced transpiration an average 8, 39, and 11% respectively. There are numerous possible explanations for differences in antitranspirant effect.

Table 3. Mean effects of biweekly applications of antitranspirants Clear Spray, Folicote, and Wilt Pruf NCF on dry weight of 'Matador' chrysanthemum (Test 1-2).

Treatment[y]	Difference in dry wt from control[z] (g)				
	1 Applic	2 Applic	3 Applic	4 Applic	Mean
Clear Spray	+0.24c[x]	+0.72c	+0.68c	+0.53c	+0.54c[x]
Folicote	+0.01c	−0.83b	−1.63a	−2.17a	−1.16a
Wilt Pruf NCF	+0.11c	+0.57c	+0.51c	+0.39c	+0.40c
Control	0.00	0.00c	0.00c	0.00c	0.00c
Mean	+0.11b[x]	+0.15b	−0.15ab	−0.42a	

[z]Mean control dry wt was 5.39 g.
[y]Includes all 3 rates of each chemical.
[x]Mean separation by Duncan's multiple range test, 5% level.

Table 5. Mean effects of biweekly applications of antitranspirants Clear Spray, Folicote, and Wilt Pruf NCF on fresh wt of 'Matador' chrysanthemum (Test 1-2).

Treatment[y]	Difference in fresh wt from control[z] (g)				
	1 Applic	2 Applic	3 Applic	4 Applic	Mean
Clear Spray	+0.14c[x]	+1.68c	+0.98c	+0.65c	+0.86b[x]
Folicote	−0.23c	−2.44b	−4.34b	−9.53a	−4.14a
Wilt Pruf NCF	+0.22c	+1.16c	+1.75c	+1.14c	+1.07b
Control	0.00c	0.00c	0.00c	0.00c	0.00b
Mean	+0.04b[x]	+0.39b	−0.62b	−2.36a	

[z]Mean control fresh wt was 54.72 g.
[y]Includes all 3 rates of each chemical.
[x]Mean separation by Duncan's multiple range test, 5% level.

Table 6. Mean effects of biweekly applications of antitranspirants Clear Spray, Folicote and Wilt Pruf NCF on height increase of 'Matador' chrysanthemum (Test 1-2).

Treatment[y]	Difference in height increase from control[z] (cm)				
	1 Applic	2 Applic	3 Applic	4 Applic	Mean
Clear Spray	+0.05c[x]	+0.70bc	+0.25c	+0.89bc	+0.47bc[x]
Folicote	+0.61bc	+1.16bc	+2.01ab	+2.66a	+1.61a
Wilt Pruf NCF	+0.34c	+0.94bc	+1.19bc	+1.23bc	+0.92b
Control	0.00c	0.00c	0.00c	0.00c	0.00c
Mean	+0.34b[x]	+0.93ab	+1.15ab	+1.59a	

[z]Mean control height increase was 21.92 cm.

[y]Includes all 3 rates of each chemical.

[x]Mean separation by Duncan's multiple range test, 5% level.

The varying persistence of antitranspirant films is an important factor in overall long-term effect. Visual examination detected no flaking, physical peeling or other visible loss of films of treated leaves over the 9-week production period. Gloss, resultant with film application, remained on treated leaves throughout production even when chemicals were only applied once. While microscopic examination was not undertaken, it appears that films of the 3 products tested were relatively persistent. This may be due to the more sheltered conditions afforded by a greenhouse. Chemicals similar or identical in composition to those used in this study have been shown to have relatively long effectual persistence (1, 12, 16).

One application of Folicote significantly reduced the 8-week water loss of chrysanthemum while it required 3 applications of Clear Spray and 2 applications of Wilt Pruf NCF to get a significant reduction. The period of time in which the films studied in these experiments continued to effectively reduce the water loss of those leaves to which material had been applied is unknown. Nevertheless, films visually persisted for 9 weeks and their effect, to some degree, could have persisted as well. Davies and Kozlowski (8) report that while films may remain on plant surfaces, ruptures or cracks can develop over stomatal pores reducing their efficiency.

From the standpoint of isolated mature treated leaves, films could remain effective for relatively long periods but realistically, when the plant is considered as a whole, this is less likely. As new growth develops on a plant, overall antitranspirant effect on a plant generally becomes diminished. It appears that the greater the initial efficiency of a product in reducing water loss, the greater the amount of new growth that would be required to reduce effect below a significant level. This is assuming continuance of effect on treated leaves.

Folicote appears to have a greater initial effect on transpiration than the other compounds tested but, at the same time, drastically reduces gas exchange (15) and may, in doing so, injure existing tissue and reduce new growth. Folicote also caused apparent thermal injury under warm greenhouse conditions. It could be speculated that a high initial efficiency in retarding transpiration, interacting with a reduction in nontreated new growth, and/or injury to existing tissue could have affected the water loss totals of Folicote treated plants. While leaf areas were taken to minimize error due to growth, it could be possible that these may have been too imprecise or taken at too infrequent an interval to offset such interactions. Tissue injury, both apparent and non-apparent, may have greatly disrupted the transpiration process as may have undetected metabolic changes.

The lesser ability of Clear Spray and Wilt Pruf NCF to lower total water loss is due, most likely, to lesser initial efficiency of these products in retarding water loss but interactions could have had an impact here as well. Clear Spray and Wilt Pruf NCF had little effect on gas exchange and net photosynthesis but appear to be capable of enhancing photosynthesis under certain circumstances (15). Overall, Clear Spray and Wilt Pruf NCF-treated plants tended to have greater fresh and dry wt than controls. A slight growth increase with a lower initial efficiency in retarding transpiration could have acted together to increase water loss totals.

We suggest that many of the water loss reductions reported in the literature, rather than being purely effects of antitranspirant film ability to retard water loss, may in fact be composite effects. Side-effects, such as on photosynthesis or tissue temp could be contributing factors in total water loss of treated plants.

Besides difference observed between the several chemicals studied, there was variation between plants in tests and between tests. These variations were most likely caused by genetic, environmental, or application differences or a combination of these.

There was a considerable variation in magnitude between the results in test 1 (summer temp) and test 2 (cooler temp). Differences between these may be explained on the basis of the large environmental differences between the 2 tests. It is assumed that photosynthetic and transpiration rates were greater during the summer and a higher degree of plant activity brought about a greater magnitude of antitranspirant effect. An adverse effect on plant temp balance due to antitranspirant application may have also played a part in test 1 results.

While there was generally an increase in effect with increase in concn of an antitranspirant, there appeared to be a greater significance with increase in the number of applications. Experiments of Hagan and Davenport (12) suggest that under normal conditions and leaf angles, increasing concn of film antitranspirant may provide little added effectiveness in increasing diffusive resistance to water vapor due to rapid runoff, except in isolated areas that result from accumulations upon drying. They also report a 3-fold increase in resistance to water vapor diffusion of lower leaf surfaces of sugar beet over the control when 1 application of a film antitranspirant was applied, but a 6-fold increase with 2 applications. Differences between numbers of applications in these experiments were often not as large as those reported by Hagan and Davenport and may be due to a very careful initial spraying with subsequent applications having less impact.

Damage in the form of foliar "burning" was observed in the greenhouse on plants treated with Folicote grown under extreme high temperatures and after two or more applications. Similar damage was reproduced in a growth chamber simulation of summer conditions (15). Thermal injury due to transpiration suppression is a highly debated phenomenon but an effect reported by researchers (13, 18, 19, 20).

Antitranspirant application appeared to affect the number of days required for chrysanthemum to flower. In tests with chrysanthemums, flowering was generally delayed and height increased with antitranspirant application. In the case of Wilt Pruf NCF, flowering was slightly hastened. Antitranspirant effects on development have been reported by others (2, 11, 17). High temp may delay flowering of chrysanthemum (referred to as "heat stall" by the florist industry). Since antitranspirant treatment may increase plant temp over controls, Interactions with ambient temp may have resulted in delayed flowering not evident with non-treated plants. Antitranspirant treatment can also alter gas exchange and photosynthesis (7, 10) and materials which hinder photosynthesis might also delay flowering. It was observed by the authors in earlier research (16) that Clear Spray, in higher concn, physically prevented petal expansion to some degree by "gluing" petals together. This "gluing" effect may be a factor in delay of flowering.

Application with Wilt Pruf NCF in a number of cases slightly hastened chrysanthemum flower development. Davenport et al.

(4) observed an acceleration in the early stages of flower opening of 'Forever Yours' roses with application of a wax film antitranspirant, Mobileaf. An improvement in the water status of treated plants or the possible enhancement of the photosynthetic process may account for more rapid floral development.

From results of these studies with chrysanthemum, it appears that antitranspirant products presently available are generally not suitable for chrysanthemum as used in this study. Davenport et al. (7) suggest that an antitranspirant might best be applied to a stage of plant development when growth is more dependent on cell expansion than on photosynthesis. Postharvest use of antitranspirants may be more desirable at the present time than use in commercial production on actively growing plants. Earlier studies by the authors (16) tend to substantiate this. While the authors do not agree with Winneberger (21), that transpiration is necessary for plant growth, they feel that, considering the expense of antitranspirant application, the risks of deleterious side-effects and complications may outweigh antitrasnpirant benefits in reducing water loss in production.

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