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Soil Temperature Effects on Cyclamen Flowering[1]

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Abstract. **Six-week treatment at a 13°C soil temperature initiated at the 4- and 6-leaf stages most effectively advanced flowering of *Cyclamen persicum* Mill. cvs. Mayer Reinweiss and Rosa von Zehlendorf-Tas. Stage of flower bud development immediately after treatment of 13°, 18.5, 24.0 and 29.5°C soil temperatures was more advanced, and mean flower bud number increased with each decrease of 5.5°C in soil temperature. At age 9 months, mean days to flower was lower and mean number of flowers per plant was higher with each decrease of 5.5°C in soil temperature. Plants treated at the 6-leaf stage flowered earlier and produced more flowers than those treated at the 4-leaf stage. The 9-month-old plants which had been treated at the 6-leaf stage were generally more advanced vegetatively than those treated at the 4-leaf stage, but the effect of soil temperature treatment on vegetative growth was negligible.**

Cyclamen has not been a popular potted plant in the U.S. recently (8), partially because of the long, costly production period. Most American growers produce flowering cyclamen in 12–15 months. Cyclamen can be grown faster and flowered earlier with higher greenhouse air temp than those traditionally recommended (10, 15). Flowering time was advanced also by higher soil temp (10). Considerable confusion remains, however, as to when cyclamen plants are most responsive to soil temp treatment and the duration of treatment required. Maatsch (10) suggested 4 weeks at 20°–22°C even though the study he cited specified a 3-month treatment period (9). He did not specify the stage of vegetative development (no. of leaves) of the plants when treatment was initiated. Later, others recommended 20°–24° at some stage of growth to speed up development and flowering, but there was little agreement as to when and how long the temp should be raised (1, 2, 4, 13). Recommendations included 3–4 weeks as soon as the seedlings were "properly up" (1), at the 4–5 leaf stage (after transplanting) for 4–6 weeks (13), 4 weeks starting at the 6–7 leaf stage (2), and at least 3 weeks at the 7–8 leaf stage (4).

Our objectives were to determine the best time for treatment and the influence of soil temp on cyclamen flowering.

Materials and Methods

Seed was sown in flats in nutrient-enriched sphagnum moss peat. The flats were kept in the dark at 20°C for 1 month until germination was visually evident, then moved into the greenhouse and grown under natural daylength at 18.5° night and 23.5°–26.5° day. Seedlings were transplanted to 7.6- × 7.6 cm spacing in flats of the same medium when the first true leaf began to develop. They were then transplanted to 10 cm plastic pots at the 3-leaf stage, 2 weeks before treatment began. Growth medium in the pots was a 9 nutrient enriched moss peat:1 loam soil mix, hereafter referred to as soil. A solution of KCl at 100 ppm K was applied twice between the first and second transplantings. Beginning 1 month after potting, the plants received an application of 200 ppm N from a 20N–8.6P–16.6K soluble fertilizer with every second watering. Adequate quantities of water and fertilizer solutions were applied to thoroughly wet the soil. Occasional additions of KCl at 1000 ppm K in solution were made when judged necessary by soil analysis.

Cultivars Mayer Reinweiss and Rosa von Zehlendorf-Tas type were used. Three crops of 'Mayer Reinweiss' were grown for the preliminary experiments from seed sown June 22, Sept. 28, and Dec. 19, 1972. Three crops of 'Rosa von Zehlendorf', from seed sown Feb. 3, March 15, and May 6, 1973 were used for the main study as plants of this cultivar were earlier flowering and more uniform in germination, plant habit, and flowering than 'Mayer Reinweiss'.

A specially constructed water tank system was used to provide controlled soil temp in the greenhouse at any time of year (12). Twelve plots (tanks), each with independently controlled water temp, were located in 4 greenhouse benches. Soil temp were 13.0°, 18.5°, 24.0°, and 29.5°C, randomized within each of 3 replications. Soil temp were recorded every ½ hr using a 12-point recorder and thermocouples placed 5 cm deep and 4 cm in from the pot edge.

Each pot was surrounded by a waterproof polyester bag somewhat deeper than the pot to permit drainage. The stiffness of the bags enabled them to hang free of the bottom of the pot. The bag-enclosed pots were inserted through holes in the plywood tank cover, so that water circulating around the pots maintained the desired soil temp.

Each plot contained 2 groups of plants or subplots, each of the same age but at different stages of vegetative development. The no. of unfolded leaves (leaf stage) was used as the criterion

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for vegetative development. Because of variations in growth, all plants in a group did not have the same leaf number. For example, plants with 4 and 5 or 6 and 7 unfolded leaves were grouped. For simplicity, only the lowest number of the 2 was used when describing leaf stage. Data from the plants in each subplot were averaged to provide a mean value for further statistical analysis.

Three preliminary experiments were used to determine the effect of leaf stage and duration of soil temp treatment on flowering time. Each experiment consisted of a treatment duration of 4 or 6 weeks, 2 separate leaf stages selected from plants with 2, 3, 4, 5, or 6 leaves, the 4 soil temp, and 3 replications of each of the 4 soil temp treatments. There were 15 plants per subplot in each experiment. After treatment, plants were grown to maturity and checked daily for date of first open flower per plant. The experiments were terminated when ca 85% of the plants had flowered.

The first cyclamen flower bud normally is initiated in the axil of the 7th leaf (5). We wished to determine if flower buds were microscopically evident in any leaf axils of plants with 4 or 6 unfolded leaves, as temperature effect could vary with whether the buds were vegetative or reproductive at initiation of treatment. Thus, using plants with 4 and 6 unfolded leaves, longitudinal cuts were made through the axil of the youngest macroscopically visible leaf, and using additional plants, each successively older leaf axil. The cut corms were fixed in FAA, dehydrated in the Sass t-butyl alcohol series (11) and embedded in Tissueprep, m.p. 56.5°C. Longitudinal sections 12 μ thick were cut from the axils of young leaves, mounted on slides with Haupt's medium and stained with safranin-fast green. Sections were mounted on slides with Permount, and examined under a microscope for presence of flower buds.

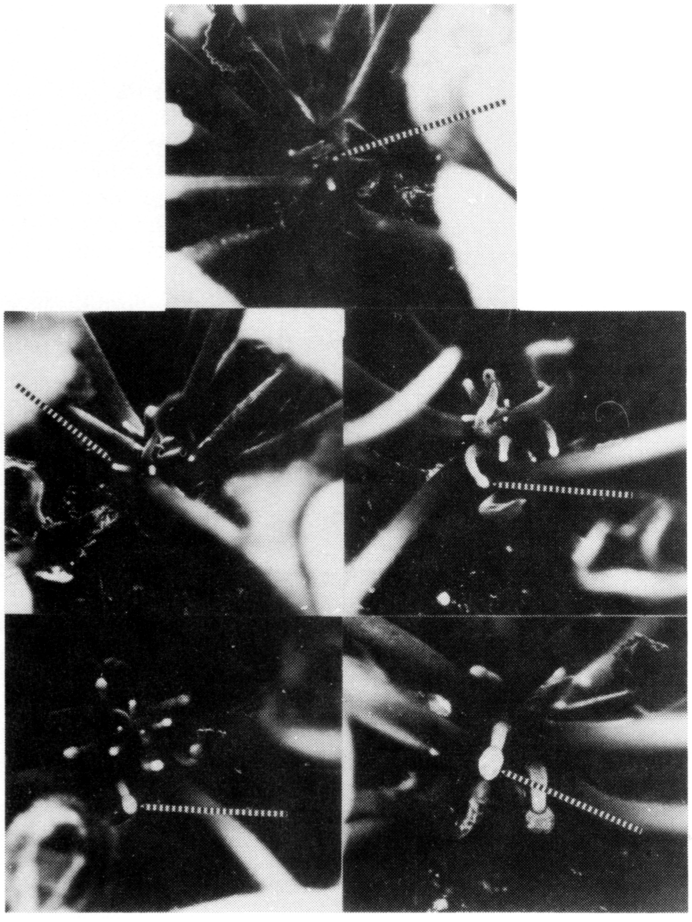

Fig. 1. Flower bud development stages after 6 weeks soil temp treatment: top to bottom, left to right: I, II, III, IV, V.

The best stages for treatment (4- and 6-leaf), as indicated in the preliminary study, were used to determine effects of 4 soil temp for 6 weeks on flower bud development in 'Rosa von Zehlendorf'. As all plants were to be grown to flowering, the following visual system of classification was established and used immediately after treatment. Stage 0 = no visible flower buds; I = flower buds visible as white-domed bumps in the axils; II = flower buds small, peduncles beginning to elongate; III = flower buds larger; IV = sepals clearly visible; V = flower buds enlarged and increased peduncle growth evident (Fig. 1). Among the plants which had 4 leaves when treatment started, so few were rated at stage V that they were combined with those at stage IV. Similarly, of those plants at the 6-leaf stage when treatment started, the few rated 0 were combined with those at stage I. Results were combined in the Chi-square analysis for independence for all sowing dates. A Chi-square test was used because each stage was relative to another and not independently defined.

The effects of sowing date, leaf stage when temp treatments were initiated, and soil temp on no. of flower buds present at the termination of the differential soil temp treatments were determined.

Final data were taken 9 months after seed was sown when at least 85% of all plants had flowered. Mean no. of days to flower for each subplot of 21 plants represented the flowering plants only.

Total flower production per plant was recorded up to 9 months after seed was sown and averaged for all plants in a subplot. Thus, mean flower numbers represent flowers on the plant plus all flowers previously removed when overmature.

Data were taken immediately after treatment on no. of leaves and plant height (above pot rim) for all plants, and at 9 months after seed was sown for plants of the last 2 sowing dates. Leaf diameter after treatment and plant diameter after 9 months were also measured.

The preliminary experiments employed a split plot in space only (each crop analyzed separately). A split plot design in time and space was used in the later study, except for the Chi-square analysis for independence of flower bud development.

Results

Plants at the 4- and 6-leaf stages subjected to soil temp

Table 1. Mean days to flower of 'Mayer Reinweiss' cyclamen in 3 experiments as affected by differential soil temp, leaf stage at time of temp treatment, and treatment duration. Each figure is the mean of 45 plants.

	Mean days to flower for plants treated for:					
	4 weeks[z]		4 weeks[y]		6 weeks[x]	
Soil temp (°C)	Leaf stage 2	4	Leaf stage 3	5	Leaf stage 4	6
13.0	307.3	317.4	254.1	237.8	242.5	243.2
18.5	325.5	307.6	246.1	241.6	254.2	255.6
24.0	322.3	307.8	255.2	243.3	261.0	262.8
29.5	318.5	308.4	256.4	248.9	269.1	260.8
F		1.31 NS	5.22*		6.46*	
F (linear regression)		–	11.35**		17.93**	
Prediction equation		–	Y = 237.9 + .5X		Y = 228.1 + 1.3X	
r (correlation of flowers' response with soil temp)		–	+0.85		+0.96	

[z]Seed sown Sept. 28, 1972, experiment terminated at 10 months.
[y]Seed sown Dec. 19, 1972, experiment terminated at 9 months.
[x]Seed sown June 22, 1972, experiment terminated at 11 months.

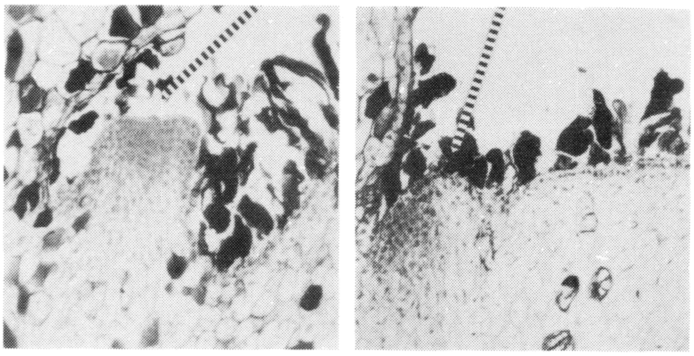

Fig. 2. Cyclamen flower bud primordia in the leaf axils of plants with 6–7 unfolded leaves (200x).

treatment for 6 weeks showed the greatest acceleration in flowering (Table 1). Plants at the 2-, 3-, and 4-leaf stages at start of treatment were not responsive to the 4-week treatment, whereas those at the 5-leaf stage were responsive. Flowering was more advanced at lower than at higher soil temp.

No flower buds were found in the leaf axils of any of the dissected plants with 4 unfolded leaves, so they were considered to be vegetative. Dissected plants with 6 unfolded leaves had flower buds in the axils of the fifth and sixth leaves (including leaf primordia) from the apex (Fig. 2), so all plants with 6 unfolded leaves were probably reproductive. Plants with 4 unfolded leaves were 8–10 leaf units old and plants with 6 unfolded leaves were 13–15 leaf units old. It was therefore concluded that flower initiation in the axil of the 7th leaf occurred sometime between the initiation of the 10th and 13th leaf.

A 13°C soil temp advanced flower bud development more than higher soil temp (Table 2). This pattern was similar for plants treated at both the 4- and 6-leaf stages. Plants at the 6-leaf stage at start of treatment were generally more advanced in flower bud development after treatment than those at the 4-leaf stage at treatment time, at any soil temp used (Table 2).

Table 2. Distribution of plants by stage of flower bud development 6 weeks after initiating soil temp treatment of plants from 3 sowing dates at the 4- and 6-leaf stage.[z]

Flower bud stage[x]	No. of plants at each flower bud stage after treatment at soil temp of: 13.0°C	18.5°	24.0°	29.5°	Expected freq.[y]	Total
			4 leaf stage			
0	6	4	23	32	16.3	65
I	7	6	19	29	15.3	61
II	30	65	111	107	78.3	313
III	71	80	37	26	53.5	214
IV	84	43	8	4	34.8	139
Total	198	198	198	198		792
			6 leaf stage			
I	3	1	2	7	3.3	13
II	6	23	69	100	49.5	198
III	43	69	77	60	62.3	249
IV	108	88	45	28	67.3	269
V	38	17	5	3	15.8	63
Total	198	198	198	198		792

[z]Chi-square test for independence = 271** for 4 leaf stage and 239** for 6 leaf stage.

[y]Calculated expected value is the same for all temp in one row.

[x]I = flower buds just visible as small bumps, II-V progressively more advanced stages.

The no. of flower buds immediately after treatment was generally highest for plants of the first 2 sowing dates exposed to the lowest soil temp (Table 3). As soil temp increased, no. of flower buds on plants of these sowing dates tended to be lower, but those from the third sowing date were unaffected. Thus, a highly significant interaction was apparent between sowing dates and temp.

Table 3. Mean no. of flower buds per plant present immediately following 6 weeks of differential soil temp treatments applied to plants at the 4- and 6-leaf stages for each of 3 sowing dates.

Soil temp[z] (°C)	Mean no. of flower buds: Sowing date Feb. 3	March 15	May 6	Total
13.0	10.1ab[y]	11.1a	8.4c	29.6
18.5	8.4c	10.9a	9.1bc	28.4
24.0	6.0ef	8.2cd	8.5c	22.7
29.5	5.3f	7.1de	8.4c	20.8
Leaf stage when treated[x]				
4	5.2a	7.3b	7.1b	
6	9.7c	11.4d	10.1c	

[z]The sowing date x oil temp interaction significant at 1% level; 126 plants per treatment.

[y]Mean separation within soil temp or leaf stage groups by Duncan's multiple range test, 5% level.

[x]The sowing date x leaf stage interaction is significant at 5% level; 252 plants per treatment.

The no. of flower buds following treatment was higher on plants treated at the 6-leaf stage than on those treated at the 4-leaf stage for all sowing dates (Table 3). Plants of both stages produced more flower buds from the second sowing than from the first. However, a significant sowing date x leaf stage interaction was apparent because plants of the second and third sowings treated at the 4-leaf stage did not differ in no. of flower buds, but those of the third sowing when treated at the 6-leaf stage produced significantly fewer buds than similar plants of the second sowing.

For plants of all sowing dates combined, days to flower increased and flower no. per plant was lower with increases in soil temp. The correlation coefficicient between days to flower and soil temp was +0.98, and between no. of flowers and soil temp, −0.99. The effect of soil temp on flowering was most evident for plants from the first sowing and least evident for plants of the third sowing (Table 4). Plants from the 3 sowing dates subjected to temp treatments at the 6-leaf stage flowered 15.3, 9.4 and 12.2 days earlier and had 6.7, 4.9 and 2.8 more flowers respectively than plants treated at the 4-leaf stage. Fig. 3 shows typical 9-month-old plants which were treated at the 4- and 6-leaf stage.

The no. of leaves unfolded immediately after treatment ranged from 11.7 to 16.9, and was highest for plants exposed to the 2 lowest soil temp. Plant height at this time ranged from 6.1 to 7.4 cm. The tallest plants were those from the first sowing treated at 18.5° and 24.0°C soil temp and from the last 2 sowings exposed to 24.0°C soil temp. Leaf number, leaf diameter and plant height were all greater immediately after treatment for plants treated at the 6-leaf stage.

The effect of the soil temp treatments on 9-month-old plants was just significant at the 5% level for leaf number and plant diameter, but was considered minor in all instances.

Discussion

Our studies showed that exposure of plants to low soil temp starting at the 4-leaf stage for 6 weeks accelerated flower bud development and subsequent flowering. This contradicts Maatsch's (10) suggestion that a moderately high soil temp

Fig. 3. Typical 9-month-old plants representing each soil temp treatment and leaf stage from the Feb. 3, 1973 sowing.

(20°–22°C) for 3 months was most effective in accelerating flowering, however, he did not state the stage of vegetative development at treatment time. This is unfortunate as leaf stage affects plant response to soil temp. Moreover, Maatsch provided his various soil temp by modifying bottom or bench heat in 3 different greenhouses, so air temp was not necessarily significantly different from soil temp in all instances. This could be a confounding factor as higher air temp for extended periods accelerates cyclamen growth and flowering (10, 15). Further, different cultivars were used in Maatsch's and our studies, and it has not been determined whether plant response to soil temp varies with some cultivars.

Anatomically, plants with 6 unfolded leaves in our study had flower buds, while plants with 4 unfolded leaves did not. Considering our findings, a 4-week low temp treatment of plants on the verge of flower bud initiation (5 leaves) is probably sufficient to hasten flowering. Cyclamen apparently does not respond to low soil temp until flower initiation has occurred. No one has reported whether one or more environmental factors trigger flower initiation and if so, the degree of control exerted. Such studies would have to be carried out with pre-6-leaf-stage plants.

We did not determine whether the low soil temp stimulation of flowering is effective on the roots or corm or on the small flower buds near the shoot apex, or on the entire plant. The receptive area could be the flower buds or plant area near the soil surface. If so, a low air temp may be just as effective as the low soil temp and easier to provide. This study determined that soil temp above 13°C provided at the 4–7-leaf stage for 6 weeks

Table 4. Mean days to flower and no. of flowers 9 months from sowing as affected by 6 weeks differential soil temp treatments applied to plants at the 4- and 6-leaf stages combined for each of 3 sowing dates.

Soil temp (°C)	Sowing date Feb. 3	March 15	May 6
	Mean days to flower		
13.0	226.8a[z]	242.9bcd	237.2b
18.5	238.9bc	246.3cde	238.1bc
24.0	248.0de	252.3ef	253.1ef
29.5	250.8de	260.6f	251.8def
	Mean no. of flowers		
13.0	14.0a[z]	13.0ab	10.5bcd
18.5	11.0abc	13.7ab	8.6cde
24.0	9.3cde	10.6bcd	7.5de
29.5	7.5de	7.2e	6.6e

[z]Mean separation within days to flower or no. of flowers by Duncan's multiple range test, 5% level.

will delay flowering and the number of flowers produced at 9 months, and that the delay will increase with increased soil temp. While we have not shown that air temp above 13° will have a similar effect, such would seem logical if the flower bud-shoot apex area were the receptive portion of the plant.

The flower bud development rate may be controlled by levels of regulating substances which in turn are modified by temp. Cyclamen has responded to gibberellic acid (GA_3) at various growth stages up to the age of 1 year (3, 6, 7, 14), and have flowered faster (6, 7, 14).

Plants treated at the 6-leaf stage always flowered first and had a higher flower count. It may be concluded that cyclamen plants that develop slower have less vigor and will flower later with fewer flowers. Such results are common, and the primary reason for comparing 4- and 6-leaf stage plants of the same age was to determine whether starting treatment of vegetative (4-leaf stage) and reproductive (6-leaf stage) plants produced a similar response. Since no interaction occurred, leaf stages in many of the analyses and tables were grouped. Development of a significant interaction would have required further experiments with the more vigorous, 4-leaf-stage plants. We can recommend that especially slow-developing plants should not be grown to maturity, however, as they require an excessively long production period.

Flowering response was a function of soil temp for all sowing dates, but it appeared that this relationship was less definite with plants from the third sowing date. This was true for no. of flower buds immediately after treatment, and for no. of flowers and days to flower at 9 months of age. Such results may have reflected a genuine time effect, or a genetic effect as the plants from the last sowing date were less uniform. Flowers of an appreciable number of the plants (5–7%) were red, while flower color of plants from earlier sowings was uniformly light salmon pink with a dark eye.

Even though soil temp altered vegetative characteristics immediately after treatment, few of the differences remained 9 months after sowing. Plants which grew more slowly in some respects because of exposure to lower soil temp usually caught up with those exposed to higher soil temp. The effect of leaf stage was consistent, however, in that the 6-leaf-stage plants were more advanced throughout the growth period.

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Ethephon as a Mechanical Harvesting Aid for Highbush Blueberries (*Vaccinium australe* Small)[1]

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Additional index words. (2-chloroethyl)phosphonic acid.

Abstract. **Application of (2-chloroethyl)phosphonic acid (ethephon) reduced fruit removal force (FRF) as much as 50% depending on concentration and time of application. Reduction in FRF allowed reduced mechanical harvesting vibration frequency which reduced damage to berries during harvest and thus increased shelf-life. Mechanical harvest was further facilitated by ethephon-induced color development and hastening of abscission which reduced the number of machine harvests required.**

The harvest of the highbush blueberry crop in Michigan is nearly 85% mechanized with 65% being accomplished by large over-row machines. In earlier reports (8, 9) injury to bearing branches was shown to be related to the vibration intensity of the mechanical harvester. Work on cherry (1, 2), orange (16), grape (4, 14) and walnut (11) have clearly shown that intensity of harvester vibration can be reduced when the FRF is reduced, either as the fruit naturally ripens (1), or when induced by a growth regulator (2, 11). Ethephon produces ethylene under acidic conditions and has been the growth regulator most widely used for this purpose. Ethylene facilitates structural degradation of the abscission zone through enhanced enzymatic activity (cellulase, methyl pectate esterase) resulting in reduced attachment between the fruit and pedicle at harvest time (1, 16).

Although ethephon has been reported to have significant physiological effects on blueberry (5, 6, 12, 13) its value as a mechanical harvesting aid was evaluated only with relation to concentration of crop maturity (5, 6). The effects on maturity are important to Michigan growers even though maturity and harvest have been based on color development rather than traditional fruit maturity indices such as sugar content or total acidity. In addition, the reported ability of ethephon to reduce FRF (1, 16) has importance to blueberry growers since harvester injury is a factor in bush survival during winter and fruit production in subsequent years (8, 9). For these reasons the efficacy of ethephon use as a mechanical harvesting aid was explored.

The existence of a respiratory climacteric in blueberries is argued (3, 10). Since the application of ethephon could have negative postharvest side effects on shelf-life and the strength of Michigan's blueberry industry has been the fresh market (Personal Communication, John Nelson, Michigan Blueberry Growers Association), shelf-life was a critical consideration in the evaluation of preharvest ethephon application.

Materials and Methods

Plant material. The experiments reported here cover 3 years (1970, 1971, and 1973). A June freeze prevented meaningful research in 1972. The 1970 and 1971 experiments were conducted on 25-yr-old 'Jersey' bushes in the Jones plantation, Grand Junction, Michigan. The bushes were large (2.5 m tall, 2 m horizontal diam) and vigorous. The 1973 experiments were conducted in the Bodke plantation, Grand Junction, Michigan, on 25-yr-old 'Jersey' bushes which were severely pruned the previous winter; plants were 1.7 m tall and 1.5 m horizontal diam.

Ethephon treatments. In 1970 a preliminary study was undertaken applying ethephon at 600 ppm to determine whether FRF as measured by a Hunter Force Gauge, could be reduced. Based on those results a detailed study was made in

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