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Performance of potato minitubers in a controlled environment after different storage periods

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Summary

Minitubers of cultivars Agria and Liseta were harvested from the same plantlets on three dates. After each harvest, tubers were dried (1 day), cured (13 days) and cold stored at 2 °C in darkness and 80% RH. Their performance was studied 65, 128, 191, 254, 317, 380, 443, 506 and 569 days after harvest. Minitubers (1 – 2 g) were planted in pots and grown for 8 weeks in a controlled environment. After 191 days of storage their growth was still extremely poor. In both cultivars, tallest plants and largest leaf areas per plant were observed in plants from tubers from the second and third harvests that had been stored for 317 days. Highest stem numbers, yields (total dry matter, tuber fresh weight) and harvest indices were achieved with 443 days storage with cv. Agria and 569 days storage with cv. Liseta. Tubers from the first harvest behaved slightly differently.

Introduction

After transplanting *in vitro* propagated plantlets in a glasshouse at high plant density, minitubers can be harvested at intervals of three weeks from the same plantlets (Lommen & Struik, 1992). The period from planting to the last harvest may extend to 10 weeks, and so with several plantings minitubers can be produced throughout the year. They can be used to produce prebasic or basic seed in the field.

After planting, the performance of minitubers may be affected by physiological age, as observed with 'normal' seed tubers (Madec & Perennec, 1955). The physiological age of tubers increases with increasing storage duration (Krijthe, 1962; Bodlaender & Marinus, 1987) and is affected by conditions and treatments during tuber growth (cf. Krijthe, 1962; Van Ittersum et al., 1992) and during storage and pre-sprouting (O'Brien et al., 1983; Van Ittersum et al., 1992). Also patterns of physiological ageing differ between cultivars.

When minitubers are required for planting in the field, the physiological status of different batches can vary considerably. Firstly, because they have been stored for different periods; the tubers originate from several glasshouse plantings and various harvests of one planting. In countries with only one planting season for field production, the storage duration may vary from a few months (for tubers in which dormancy has just ended) to more than 1 year (for tubers that were dormant at the start of the planting season in the preceding year). Secondly, minitubers originating from subsequent harvests of one glasshouse planting differ, even if the time elapsed after harvest is similar. This is illustrated by differences in dry matter concentration (Lommen, 1993a), length of the dormant period (Lommen, 1993a) and weight losses during storage (Lommen, 1993b). Finally, the physiological status of minitubers from different plantings may vary because the external conditions during the course of a year change, even in a controlled glasshouse. As a result of a varying physiological nature, the performance of the minitubers may vary too.

Because there are no reports on physiological ageing of minitubers or other types of small tubers, the performance of minitubers under controlled conditions was studied after storage up to 1.5 year.

Materials and methods

Minituber production. Details on production of the minitubers in this experiment were reported by Lommen (1993a); minitubers of cvs Agria and Liseta were produced on *in vitro* propagated plantlets grown in a soil-perlite mixture at 350 plants m^{-2} in a glasshouse under tuber inducing conditions. Tubers were harvested on three dates at 3-week intervals (May 25, June 16 and July 6) after removing plants from the growing medium. After the first two harvests, plants were replanted deeper than originally.

Minituber storage. After harvest, minitubers were left to dry at room temperature for 1 day in a thin layer in open metal boxes, to allow removal of soil. They were then sorted by fresh weight and cured at 18 °C in complete darkness at 80% RH for 13 days. Long-term storage was at 2 °C in complete darkness and 80% RH. Maximum length of the storage period of tubers from each harvest was 569 days, consisting of (a) the drying period of one day, (b) the curing period of 13 days and (c) the cold-storage period up to 555 days. During curing and cold storage, tubers were kept in a thin layer in crates lined with cheese-cloth; those that deteriorated were discarded.

Performance tests. Performance tests were carried out after 65, 128, 191, 254, 317, 380, 443, 506 and 569 days of storage using minitubers (1.00 – 1.99 g) of both cultivars from all harvests. Tests were started with tubers from different harvests at 3-week intervals. At the start of the tests, tubers had accumulated respectively 358, 484, 610, 736, 862, 988, 1114, 1240 and 1366 day-degrees >0 °C after harvest. Room temperature during the first day was assumed to be 22 °C. With cv. Agria, 18 tubers were used in each test. With cv. Liseta, fewer tubers were produced and the numbers used in each test are shown in Table 1. Tubers were not presprouted or conditioned and were planted singly 3.1 cm deep in 20 cm diameter pots containing 5 l of potting soil. No fertilizer was applied. Pots were arranged in two contiguous rows in a growth room at 18/12 °C day/night and 12 h photoperiod. Light (90 Watt m^{-2}, total radiation at plant level) was supplied by Philips SON-T and HPL-T lamps, supplemented by fluorescent tubes (Philips-33). Missing tubers of cv. Liseta were replaced by other minitubers (not analysed) to give 36 pots in each test. The position of the pots in the growth room was changed every 3 weeks to enable similar positions of pots in all tests. Plants were harvested 8 weeks after planting. Tubers used in the last test of cv. Liseta were weighed at room temperature at regular intervals during storage to determine weight loss during storage (Lommen, 1993b).

Table 1. Number of tubers from three harvests of cv. Liseta used in performance tests after storage periods of 65 to 569 days.

Harvest	Duration of storage (days)								
	65	128	191	254	317	380	443	506	569
First	10	10	18	18	10	-	-	-	18
Second	18	10	9	18	14	15	-	-	18
Third	18	18	18	18	18	18	9	-	18

Observations. Shoot emergence was recorded daily, starting with minitubers from the third harvest in the third performance test. In later tests, emergence date during the weekend was estimated. All stems originating from 1 tuber were regarded as 1 plant. At 8 weeks after planting, the weights of stems, leaves (petiole, rachis and leaflets), stolons and tubers were recorded. Leaf area was determined and numbers of main stems (above-ground stems arising from the mother tuber) were recorded. Stem length of the longest main stem was measured from the mother tuber to the point where new leaves appeared. Harvest index was the dry weight of tubers as a percentage of total dry weight, excluding roots.

Results

Emergence. After storage for 65 days, most minitubers were dormant and did not emerge within the 8 weeks period (Figs 1A and B). After tubers had been stored for 128 days most plants emerged, and with further storage the proportion of emerged plants rapidly increased up to 100% whereas the time taken to emergence decreased (Figs 1C and D). Emergence was slightly slower with cv. Agria than with cv. Liseta. However, when tubers of cv. Agria were stored for more than 443 days, the time taken to emerge increased and at the end not all tubers produced a plant. By contrast, emergence of cv. Liseta at that time still was rapid and complete.

As all plants had 8 weeks available for emergence and post-emergence growth, the time to emergence directly affected the length of the post-emergence period; the average number of days with above-ground shoots can be derived from Figs 1C and D. With cv. Agria, this was maximum from 317 to 506 days of storage, with cv. Liseta from 317 days of storage onwards.

Stem number. Minitubers usually produced one main stem following storage periods up to 254 days (Fig. 2). After longer storage, numbers of main stems increased. In cv. Agria, maximum numbers were produced after 443 days storage (2 – 3 main stems per plant), whereas numbers of main stems decreased after prolonged storage. In cv. Liseta, highest numbers of main stems were recorded after the longest storage period tested (569 days, 4 – 6 main stems per plant). At these high stem numbers, however, stems were much thinner and weaker than at the lower stem numbers observed earlier.

Differences in stem numbers produced by tubers from the three minituber harvests never were significant with cv. Agria. With cv. Liseta, tubers from the first harvest

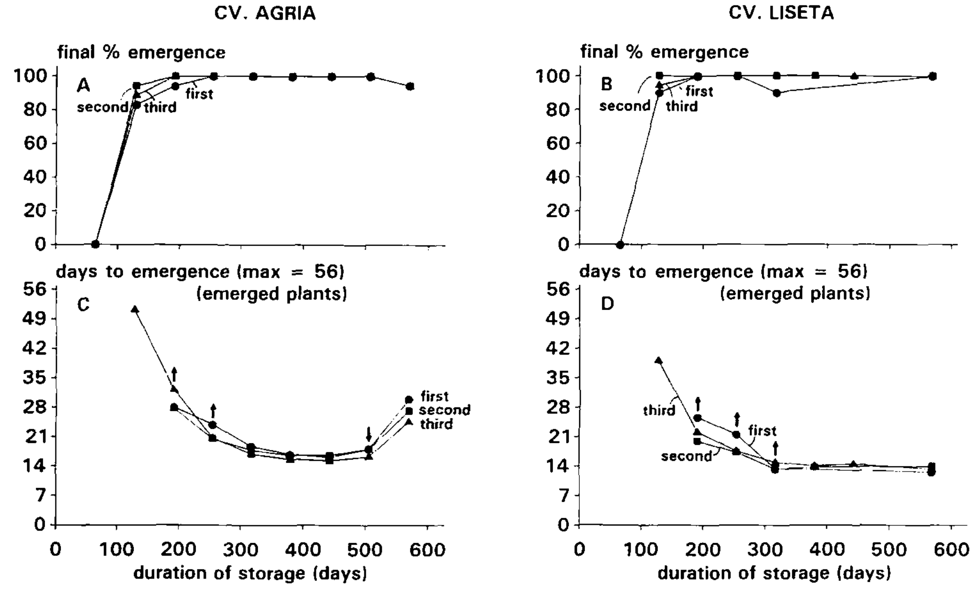

Fig. 1. Influence of length of storage period on the percentage emerged plants (A, B) and the number of days to emergence of emerged plants only (C, D) from minitubers originating from three repeated harvests of the same plantlets. Duration of test: 56 days. A and C: cv. Agria. B and D: cv. Liseta. Significant differences ($P < 5\%$) between harvests are indicated in the graphs as: ↑ = highest value differs from the others, ↓ = lowest value differs from the others, ↕ = only highest and lowest values differ, a = all values differ from each other.

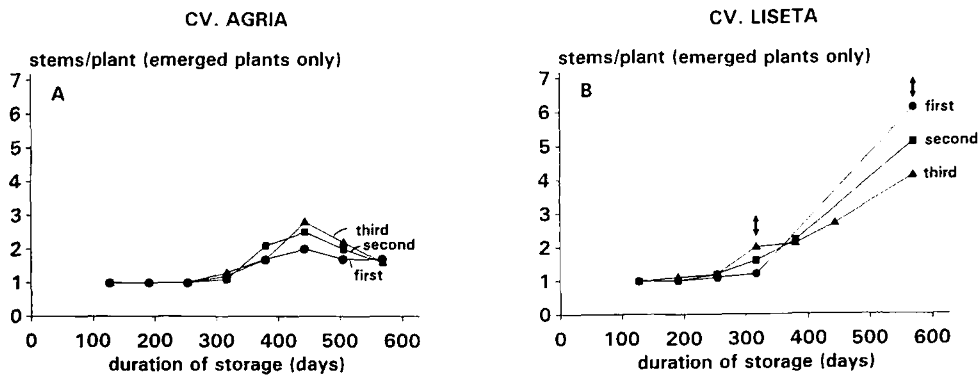

Fig. 2. Influence of length of storage period on numbers of main stems produced by minitubers (emerged plants only) originating from three repeated harvests of the same plantlets. A: cv. Agria. B: cv. Liseta. Untransformed data, assessed 8 weeks after planting. Significant differences between harvests (see Fig. 1) were assessed after square root transformation.

tended to produce fewer stems than those from the third harvest when given intermediate storage periods (difference significant after 317 days of storage), but more stems following very long storage (569 days).

Stem length. In both cultivars, length of the longest main stem per mother tuber increased with increasing storage duration up to approximately 317 days (Fig. 3). Thereafter, stem length was more variable, and tended to decrease.

Before maximum stem length was achieved, tubers from the first harvest often produced shorter stems than those from later harvests. In cv. Agria, the decrease in stem length following prolonged storage was initially less with tubers from the first harvest.

Leaf area. In plants of both cultivars originating from tubers of the second and third harvests, leaf area per plant increased to approximately 4000 – 4500 cm^2 with increasing storage duration up to 317 days (Figs 4A, B). In cv. Agria this was mainly due to a larger leaf area per stem (Figs 2A, 4C). In cv. Liseta, the leaf area per stem increased only with storage up to 254 days for tubers from the third harvest (Fig. 4D), but leaf area per plant was larger after 317 days of storage because of high stem numbers. With storage periods longer than 317 days, leaf areas per stem decreased in both cultivars (Figs 4C, 4D). As stem numbers did not compensate for the smaller leaf areas per stem, leaf area per plant decreased after maximum values were achieved. This was most clear with cv. Agria.

Plants originating from tubers of the first harvest usually produced smaller leaf areas per plant than those of later harvests after storage for up to 317 days. With cv. Agria, they apparently needed longer storage periods to achieve maximum leaf areas. Nevertheless, with both cultivars, plants originating from tubers of the first harvest again had smaller leaf areas than those of later harvests, when stored for 569 days.

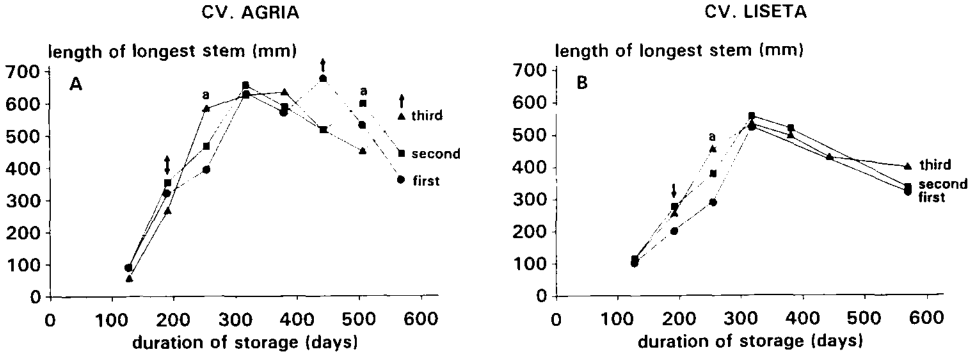

Fig. 3. Influence of length of storage period on the length of the longest main stem of emerged plants from minitubers of three harvests, 8 weeks after planting. A: cv. Agria. B: cv. Liseta. For significant differences see Fig. 1.

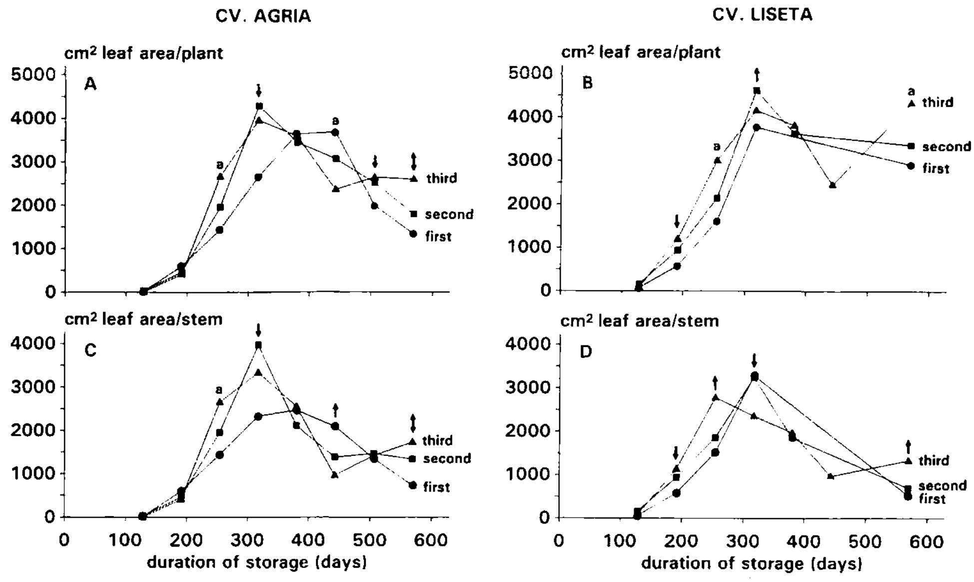

Fig. 4. Influence of length of storage period on leaf area per plant (A, B) and per main stem (C, D) produced by emerged plants of minitubers from three harvests, 8 weeks after planting. A and C: cv. Agria. B and D: cv. Liseta. For significant differences see Fig. 1.

Total dry matter production, yield of progeny tubers and harvest index. Total dry matter production (excluding roots, Figs 5A, B), fresh weight of progeny tubers (Figs 5C, D) and harvest index (Figs 5E, F), showed similar responses to increasing storage duration. In cv. Agria, yields increased with increasing storage up to 443 days to about 30 g dry matter and 110 g fresh tuber weight per plant. The harvest index had by that time increased to about 60%. After 569 days of storage, both yields and the harvest index had clearly decreased. With cv. Liseta, highest yields and highest harvest indices were achieved with the longest storage period tested. Maximum yields were higher than those obtained from cv. Agria, although maximum harvest indices were almost similar.

When differences in yield between the 3 tuber sources were significant, plants originating from tubers of the first harvest generally yielded less. These differences were most obvious with cv. Liseta (Figs 5B, D). By contrast, harvest indices of plants originating from tubers of the first harvest did not consistently differ from those of later harvests.

Discussion

Performance of minitubers after storage. Minitubers (1 – 2 g) showed patterns of increasing and (eventually) decreasing performance with increasing storage duration similar to those known to occur with normal seed tubers (Bodlaender & Marinus, 1987).

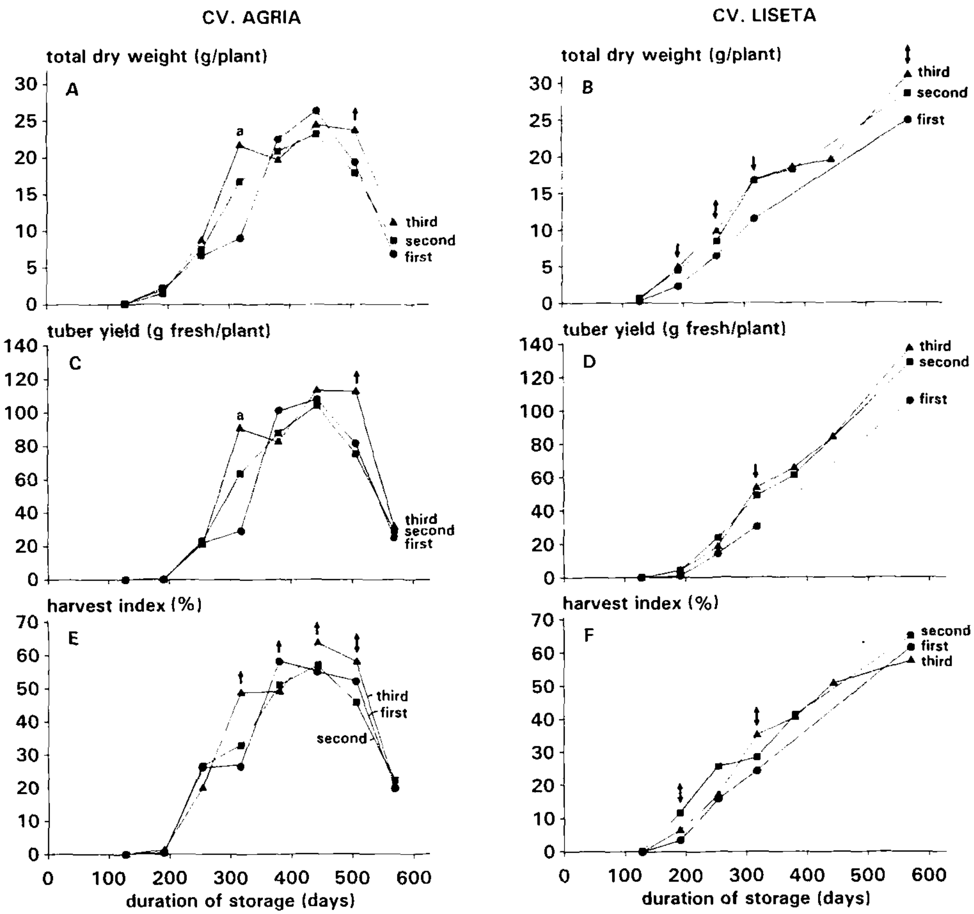

Fig. 5. Influence of length of storage period on total dry matter (A, B), tuber fresh weight (C, D) and harvest index (E, F) produced by emerged plants of minitubers from three harvests, 8 weeks after planting. A, C and E: cv. Agria. B, D and F: cv. Liseta. For significant differences see Fig. 1.

As in normal tubers, patterns were cultivar dependent. Cv. Agria performed best after storage periods of approximately 443 days when rate of emergence, number of main stems, total dry weight and tuber fresh weight were highest (Figs 1, 2, 5); with longer storage, performance declined considerably. By contrast, cv. Liseta produced highest stem numbers and highest yields after the longest storage period in this experiment (569 days). However, not all plant characteristics were maximal after the indicated storage periods. For example, maximum leaf areas and stem lengths were observed following shorter storage (Figs 3, 4).

Patterns of physiological ageing of tubers slightly differed between harvests. With cv. Agria, the rate of increase in stem length, leaf area per plant and yield with increasing storage duration appeared to be lower when tubers originated from the first than from later harvests, whereas the decrease after maximum values were attained appeared to be greater with tubers from the first harvest (Figs 3A, 4A, 5A, 5C). With cv. Liseta, the performance of tubers from the first harvest was much poorer than that of tubers from later harvests (cf. Figs 5B, D), which may have resulted from slower physiological ageing or from a smaller amount of carbohydrate reserves in minitubers from the first harvest. Average tuber weights of cv. Liseta from the first harvest were slightly lower than from later harvests (respectively 1.2, 1.4 g; Lommen, 1993a). Minitubers from the three harvests were compared after similar storage durations. At a certain calendar date, however, minitubers from the three harvests differ in storage duration by 21 days each. Simultaneous planting, approximately 10 months after the last harvest, will reduce differences in performance between tubers from the first and second harvests, but will increase differences between those from the second and third harvests.

Extrapolation to field performance. Because conditions during the tests differed from those prevailing in the field, we cannot predict precisely the effect of storage duration on field performance of minitubers. Effects of physiological age are most clear under adverse conditions (Allen et al., 1979), whilst post-emergence conditions in the field also may level out the effects of physiological age (Fischnich & Krug, 1963). However, results (Figs 1 – 5) show that differences in performance are to be expected between cultivars and between tubers stored for different periods.

It is likely that the optimum storage duration of minitubers for field planting will be shorter than those giving the highest tuber yields in our tests (Fig. 5). Minitubers will usually be presprouted and hardened, and this increases their physiological age (cf. Allen et al., 1992). Also plants from physiologically younger tubers may develop more haulm before tubers are initiated but may, when the growing period is long enough, achieve higher tuber yields because of greater light interception (O'Brien et al., 1983). Therefore, the larger leaf areas of our plants after storage periods shorter than those giving highest yields in performance tests may result in higher yields of progeny tubers under field conditions when the growing period for seed production is long enough. However, leaf areas achieved by longer-stored minitubers may be high enough to give complete ground cover under field conditions, whilst the rate of tuber bulking may be higher. This will depend on plant density and arrangement used in the field. It seems unlikely that the optimum storage duration for field planting will be much shorter than 317 days, because emergence is likely to be delayed (Fig. 1) and therefore the length of the post-emergence period reduced.

Practical implications and manipulating physiological ageing of minitubers. As minitubers have a dormant period (Lommen, 1993a), it is necessary to produce them some time before they are planted in the field or to break their dormancy artificially. Our results suggest that their performance may be poor if they are produced 6 or 7 months or less before planting. Therefore, they should be produced earlier and stored until their performance is better (10 – 11 months under our conditions) or optimal.

By increasing temperature during the whole or part of the storage period, the ageing of tubers possibly could be accelerated. Heat treatments soon after curing may increase vigour shortly after the end of dormancy (Van Ittersum et al., 1992) and presprouting at high temperatures in light followed by cold storage (O'Brien et al., 1983) could increase their physiological age. By adjusting the timing of this high-temperature presprouting, it is possible that sprout numbers also could be manipulated. However, desprouting following high temperature storage (Bodlaender & Marinus, 1987) would seem to be undesirable for practical use as a significant amount of the minituber reserves already may have been spent in producing the first sprout.

The timing of production of minitubers with optimal physiological age may pose problems when minitubers are produced throughout the year in countries with one planting season. Very young tubers will need to be stored until the next planting season. Although most minitubers ≥ 0.5 g can be stored for more than 1.5 year (Lommen, 1993b), our results indicate that not all cultivars perform well after storage for that period (Figs 5A, C). Also, the timing of production of minitubers and storage conditions will require correct adjustment to fit the patterns of physiological ageing of different cultivars, because age may have a large effect on their performance.

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