Nursery propagation, field adaptation and carbon sequestration potential of Pistacia chinensis (Chinese Pistachio)

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ABSTRACT:

The study was conducted to assess appropriate means of nursery propagation and to evaluate field adaptation and carbon sequestration potential of *Pistacia chinensis*- a root stock for edible nut bearing pistachio. The trial was conducted at Debre Zeit and Wondo Genet in 2006. Matured seeds of the species with protective seed coats were sown on standard soil mixture (SSM) that comprised 3 % top soil, 2 % cow dung and 1 % sand and their germination was compared with seeds with protective seed pods that were sown on composted farm yard manure (FYM). Two independent experiments were conducted in completely randomized design with four replications, each replication containing one hundred pure viable seeds. Mean comparisons of germination percentages revealed highly significant differences between the treatments (seeds with protective seed coats sown on farm yard manure) and control groups (seeds with protective seed coats sown on standard soil mixture) at $P<0.05$. Thus, the most viable means of propagating *Pistacia chinensis* under the nursery conditions of Debre Zeit was sowing seeds with pods on farm yard manure. In a separate experiment, seeds without pods were also sown in replicates on standard soil mixture and their germination was compared with that of intact seeds (Seeds with their pods) sown on standard soil mixture. Mean comparisons of germination percentages for seeds without pods disclosed a highly significant decline as compared to the control groups i.e. intact seeds at $P<0.05$. Height and collar diameter of trees averaged 194.61cm and 4.82 cm for Debre Zeit and thus are found significantly different from their counterparts (141.1cm for height and 3.35cm for diameter) at Wondo Genet.

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There was no significant difference between survival percentage of trees at Debre Zeit (82.6%) and Wondo Genet (90.6%) based on comparison of error bars. To calculate the carbon sequestration potential of established trees, a total enumeration on height and diameter of 75 trees on research plot at Debre Zeit was carried out and the resulting data was fed to established allometric relations. The total amount of carbon sequestered by the trees calculated through allometric relations amounted to 1.33tons/ha/year.

Key words: Carbon sequestration, FYM, nursery propagation, SSM. *Pistacia chinensis*

INTRODUCTION:

Tropical fruit trees supplement and improve the quality of diets. Many of the species have multipurpose uses as they produce non-food products such as fuel, timber, fodder, medicines and industrial products for smallholders in addition to the edible fruits. In Africa, domestication efforts are already showing success in meeting livelihood security needs of farmers and in conserving biodiversity (Tesfaye and Mohamed, 2004). Out of many economically important exotic tree species, *Pistacia chinensis,* which is also known vernacularly as Chinese pistachio, is well adapted to drier areas. *P. chinensis* is a member of the family Anacardiaceae with kaleidoscopic colors despite prolonged heat and a dearth of summer rain.

P. chinensis is native to China. It stands up to pollution, drought, nutrient poor soil, or restricted root space and still grow into an impressive 20 to 35 foot tree. Its notable adaptability to drought conditions is attributed to its tap root which provides strong anchorage as well as the ability to reach deeper water sources (Koller, year unmentioned). Pistacia is a xerophytic genus, which is shown by the presence of many adaptations to aridity, such as advanced development of palisade tissue and extensive root growth (AL-Saghir et al., 2006).

P. chinensis requires good soil drainage and exposure to full sun to encourage optimum growth and best form. Its spring flowers are not visible from distance. It produces bitter oily nuts that have comparable size with ground nuts on the female trees. The nuts are attractive like berries maturing from yellow to red and ultimately metallic blue if they haven't been eaten up by birds. It is a dioecious tree, meaning male and female flowers are produced on separate trees. It has an underutilized potential for wider use in urban street tree plantings and in other adverse sites due to its drought tolerance, adaptability, moderate size, and wonderful form and radiant color of the leaf during autumn. Chinese Pistachio grows quickly in full sun to partial shade on moderately fertile, well-drained soils and will withstand heat and drought extremely well. The crown is quite round and symmetrical on older specimens when grown in full sun but becomes misshapen in too much shade - best for full sun areas. It grows in clay, loam, or sand in a wide range of soil pH and can be used as the under stock on which the commercial pistachio nut (*Pistacia vera*) is grafted (Edward and Dennis, 1994).

There are 11 species (*P. atlantica, P. cabulica, P. chinensis, P. falcata, P. integerrima, P. vera, P. kurdica, P. mutica, P. palestine, P. terebinthus and P. khinjuk)* of genus *Pistacia* according to Zohary's classification. But only four species are widely used in the pistachio industry. The other species grow in the wild and are used as root stock sources and for fruit consumption, oil extraction and soap production (Zohary.1952; AL-Saghir et al., 2006). The nut produced on *P. chinensis* cannot be eaten since it is not the edible pistachio tree. However, P. *chinensis* could be used as an under stock for growing *Pistacia vera,* the real nut. species. *P. vera, commonly* known as Pistachio, has edible seeds and of considerable commercial importance. Pistachio nuts provide fiber, vitamins B1 and B6, thiamin, magnesium, phosphorus and copper, plus smaller amounts of other nutrients (Wood, 2004).

P. vera, with reduced vigor, is the most used rootstock in the world. However, commercial pistachio nursery production needs to raise fast growing rootstocks to allow early budding and transplanting to orchard. In addition, vigor is a desirable character in pistachio rootstocks, due to its effect on the time needed by the scion to form a large canopy (related with yield capacity) and on the adaptation of the tree to adverse growing conditions in which usually the crop is placed.

Fig.1. Freshly collected seeds of *P.chinensis* **Fig.2.** Extracted nuts of *P.chinensis*

The achievement of a good rooting system is a very important characteristic for transplanting to the orchard. The interest for pistachio rootstocks is mainly related to their capacity of adaptation to environmental conditions in which the crop is developed (Vargas, et al. 1998). Many pistachio species are not cultivated for their nuts, but instead are used as rootstocks to which the upper, nut-bearing portion of the tree, or scion, is grafted. Or, these species are planted as street trees, especially those like *Pistacia chinensis,* which has a spectacular red and orange foliage in fall (Wood, 2004).

Except a few introduced mother trees at Debre Zeit Agricultural Research Center, *P. Chinensis* is virtually unknown all over Ethiopia. Its planting was also restricted in the research center because of its very low germination percentage when seeds were sown on nursery soil mixes used for seedling production of other tree species. In addition, the tree's hardiness potential has not been fully evaluated through research across locations and very little work was undertaken on popularizing the species for large scale propagation and street side planting. With the intention of filling this research gap, the present study was initiated in 2006 primarily focusing on evaluating the nursery propagation techniques and field adaptation potential and growth performance of the species across location. The two locations considered for field adaptation and growth performance study were Debre Zeit and Wondo Genet research stations. Activities are already underway to use the tree in street side planting to check its adaptability to the soil and climatic conditions of Debre Zeit area. Based on the research results it was found to be very satisfactory. No remarkable damage due to environmental stress, pest or disease has been observed during the last six years, and relatively faster growth has been registered. With a better resistant and adaptable root stock in the field it is planned to proceed experimenting with the production of edible pistachios through vegetative propagation with compatible and commercial species in the future.

Considering its high leaf biomass production and vegetative growth, there was also an interest in estimating the carbon sequestration potential of the species at Debre Zeit through non-destructive sampling technique. i.e. taking live tree data on height and collar diameter and putting the data into already established allometric relationships. One way to estimate how much carbon is in an acre of forest is clear cutting one acre/ha of forest, measuring the weight of all organic material harvested, and then analyzing the material for the percentage of carbon within it. While it would give a very precise estimate, the utilization of this method is not a very ecologically-friendly way to study nature. A less harmful way to carry out the estimate is to develop an allometric equation that will allow to estimate the mass of a tree from a few simple measurements of it, and then to apply this equations to the trees in a forest. The term allometry is defined as "the measure and study of relative growth of a part in relation to an entire organism or to a standard"(Janssens et al 2003). Thus, the carbon sequestration potential of the species on the research field was estimated using established allometric relationships developed on the basis of the total or green weight of the live trees. The growth parameters considered for evaluation of field adaptation included tree height, collar diameter and survival.

The main Objectives of this study are: -

-To select appropriate nursery propagation practices for the species;

-To evaluate across location adaptability and field performance of the species;

- To establish root stocks for future vegetative propagation with *Pistachia* species;

-To estimate carbon sequestration potential of the established stand.

Materials and methods:

The experiment was conducted in two phases. The first phase was on nursery propagation practices at Debre Zeit and the second was on field adaptation and growth performance evaluation at Debre Zeit and Wondo Genet Agricultural Research Centers.

Nursery:

Freshly collected seeds were air dried on plastic mats for two weeks. The air dried seeds were immersed in a bowl of cold water as a simple test for their purity in the lab. All those pods that seemed to be sinking were discarded for they were suspected to be either empty or impure. Unlike other tree seeds, it is the pure, viable air dried seeds of *P. Chinensis* that floated. The floated seeds were then recovered and socked in cold water to loosen the fleshy outer layer (exocarp and mesocarp) that surround the hard seed bearing shell or endocarp containing two greenish cotyledons. After a through removal of the fleshy outer layer pure seed pods containing cotyledons were left socked in cold water for 24 hours. This was to induce imbibitions and make the seeds ready for sowing.

For the germination test, completely randomized design (CRD) with three replications was used. A total of 100 seeds of the species with pods were sown on standard soil mixtures (3% top soil: 2% manure: 1% sand) per replication. In a separate experimental set up, 100 seeds of the species with pods were sown on farmyard manure per replication. In both cases the sown seeds were covered with light soil and mulched uniformly to facilitate warmth and smooth percolation of moisture during watering. Data on germination count was taken starting from three weeks after sowing on every other day for the test duration of sixty days. Independent sample t-test in SPSS was used for data analysis. To evaluate the effect of pod removal in facilitating the emergence and enlargement of essential structures (plumule and radicle) a third experimental set up was laid out in CRD with three replications. This was done by sowing seeds without pods on standard soil mixture and comparing their germination with that of intact seeds (Seeds with their pods) sown on standard soil mixture. Data on germination count was taken starting from three weeks after sowing on every other day for the test duration of sixty days. Independent sample t-test in SPSS was used for data analysis.

Field adaptation:

To evaluate across location performance differences and species adaptation, 75 mature twelve months old seedlings of *P. chinensis* were planted in three plots at Debre Zeit and Wondo Genet Agricultural Research atations in June 2006. A plot comprised 25 trees. Spacing between trees in the row was 2.5m while the space between plots was 3m. The altitude of the testing site at Debre Zeit is 1800m a. s. l and receives an annual mean rainfall of 740mm while the site at Wondo Genet is situated at an average elevation of 2000m and receives an annual mean rainfall of 1200mm. Two sites were selected in order to evaluate the effect of location difference (rainfall, temperature, soil and other biophysical attributes in general). Appropriate silvicultural practices like weeding and mulching were provided for the planted seedlings and the adaptive potential of the species under the prevailing condition of the test sites was evaluated with no supplementary irrigation in the off-season. Data collected on mean survival, collar diameter and height after six years of planting were subjected to two tailed independent samples t-test in SPSS at $P<0.05$ for statistical analysis.

Estimation of carbon sequestration potential:

From the already established plots at Debre Zeit that comprised a total of 75 trees, height and diameter of all individual trees were measured. To assess the carbon sequestration potential of the stand the following stepwise procedures, developed by Janssens et al (2003), were followed:

a) Determination of the total(green) weight of the trees;

b) Determination of the dry weight of the tree;

c) Determination of the weight of carbon in the tree;

d) Determination of the weight of carbon dioxide sequestered in the tree;

e) Determination of the weight of carbon dioxide sequestered in the tree per year.

The algorithm to calculate the green weight of the tree is:

$W= 0.25D^2H$, for trees with D<11

$W=0.15D^2H$, for trees with D>=11

Where W= above ground weight of the tree in pounds (0.49 kg)

D= diameter of the trunk in inches (2.54 cm)

H= height of the tree in feet (0.33 meter)

It is assumed that the root system weighs about 20% as much as the above-ground weight of the tree. The below ground weight of plants on average is about 20% of its total weight. Therefore, to determine the total green weight of the tree, the above-ground weight of the tree is multiplied by 120%.

The average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, the weight of the tree is multiplied by 72.5 % (Scott De Wald, 2005). The average carbon content is generally 50% of the tree's total volume. Therefore, to determine the weight of carbon in the tree, the dry weight of the tree is multiplied by 50% (Richard A. B, 1992). To determine the weight of carbon dioxide sequestered in a tree the molar composition on CO_2 was taken into account. CO_2 is composed of one molecule of Carbon and 2 molecules of Oxygen.

The atomic weight of Carbon is 12.001115.

The atomic weight of Oxygen is 15.9994.

The weight of CO_2 is C+2*O=43.999915.

The ratio of CO_2 to C is 43.999915/12.001115=3.6663.

Therefore, to determine the weight of carbon dioxide sequestered in the tree, the weight of carbon in the tree is multiplied by 3.6663. Ultimately to determine the weight of CO_2 sequestered in a tree per year the weight of the carbon dioxide sequestered in the tree was divided by the age of the stand which is already known.

Results

The best propagation medium and method for large scale seedling production of the species has been identified. Mean comparisons of germination percentages using two tailed independent samples t- test in SPSS revealed highly significant differences between the treatments (Farm yard manure) and control (Standard soil mixture) groups at $P<0.05$. Sowing seeds of *P. chinensis* with pods on farm yard manure gives significantly better germination percentage (at $p<0.05$) than doing it so on standard soil mixtures (Fig.4).

It was also observed that seeds that were sown on standard soil mixtures have difficulty in penetrating substrate upwards during emergence of the essential structures, .i.e. the plumule and the radicle. As germination of Pistacia is epigeal most of the seedlings soon died out just after emergence due to the very soft and delicate nature of the plumule. This problem however was not encountered when seeds were raised on a more porous and coarse textured growing medium like composted farm yard manure. Therefore, significantly better germination percentage (at<0.05) was observed using the latter technique. This could partly be attributed to the reason that composted farm yard manure is an approximate simulation of the forest floor that is considered to be the most convenient propagation medium for naturally falling seeds of *P. chinensis* at maturity.

Seeds with their pods removed were also sown in replicates on SSM to see if the removal of pods would make germination better. But the experimental results revealed to the negative, i.e. most of the seeds sown without pods decayed (Fig.4) in the soil prior to germination due to the direct contact of the seed with soil moisture leading to a very low germination percentage.

Mean comparisons of germination percentages using two tailed independent samples t- test in SPSS revealed a highly significant decline in germination of seeds sown without pods and the control groups, i.e. seeds sown with pods at P<0.05. The data analysis produced a t_{obs} value of 2.151, with df =6, p=0.075. Therefore, we reject the null hypothesis and conclude that sowing seeds of *P. chinensis* with pods gives significantly better germination percentage (at p<0.05).

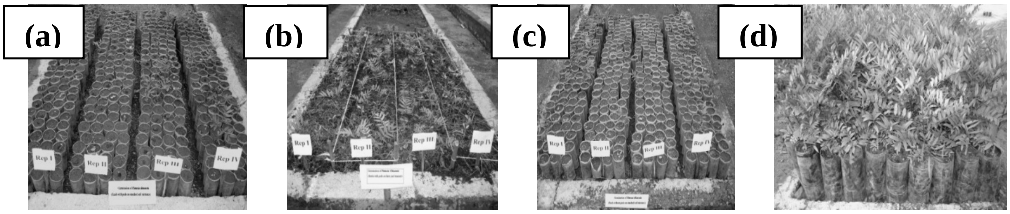


Fig.3.Comparison of germinations under different substarate conditions. **(a)**Germination of *p.chinensis* seeds with pods on standard soil mixture. **(b)** Germination of *p.chinensis* seeds with pods on composted farm yard mannure**. (c)** Germination of *p.chinensis* seeds with out pods on standard soil mixtures. **(d)** Twelve months old *p.chinensis* seedlings ready for planting.

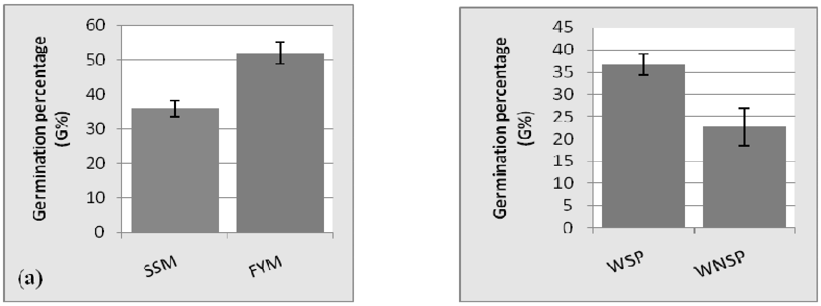


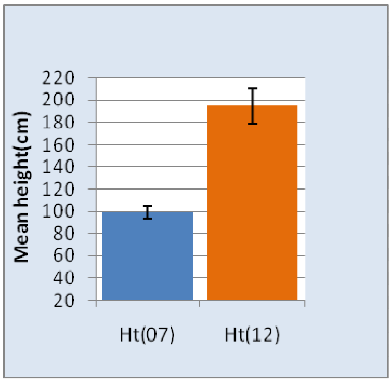
Fig.4. Germination percentages under varying substrate conditions and planting methods.

Error bars are SEM with n=4 **(a)** *P. chinensis* with pods under different substrates. **(b)** *P. chinensis* with no seed pod on standard soil mixture. SSM: Standard soil mixture. FYM: Farm yard manure.WSP: With seed pod. WNSP: With no seed pod.

The tree characteristics considered for evaluation of field adaptation and growth performance included tree height, collar diameter and survival. Twelve months old seedlings of *P. chinensis* were planted on test plots at the mentioned locations. Accordingly, the species gave a mean height and diameter of 194.61cm and 4.82 cm, respectively in six years at Debre Zeit. Mean comparisons of height and diameter growth using paired two tailed t- test in SPSS showed significant differences between two and six years after planting at $P<0.05$. This was revealed by a t_{obs} value of 5.721, with df =4, p=0.005 for height and a t_{obs} value of 2.883, with df =4, p=0.045 for diameter (Fig.5&6).

Height performance of the tree species was significantly better at Debre Zeit than Wondo Genet. This difference was disclosed through the use of error bars. As the upper error bar of height values at Debre Zeit did not overlap with the range of height values at Wondo Genet there is more likelihood that these two mean height values differ significantly (Fig.7a). There was also significant difference in mean diameter growth across locations (Fig.7b). Accordingly the upper error bar of height values at Debre Zeit did not overlap with the range of height values at Wondo Genet. Across location survival percentage of the species was not found out to be significantly different. As the upper error bar for survival percentage at Wondo Genet overlaps with percentage values in the error bar for Debre Zeit there is a much lower likelihood that these two survival percentages values differ significantly (Fig.7c).

The carbon sequestration potential of the species at Debre Zeit was calculated using the allometric relationships specified in the materials and methods. To calculate the above ground weight of a tree in pounds, the relation W= 0.25D2H was used as all the trees had diameters below 11 inches. Sequential steps to calculate carbon dioxide sequestered in the tree per year were followed to finally arrive at the amount of carbon dioxide sequestered on hectare basis which is 1.33tons/ha/year.



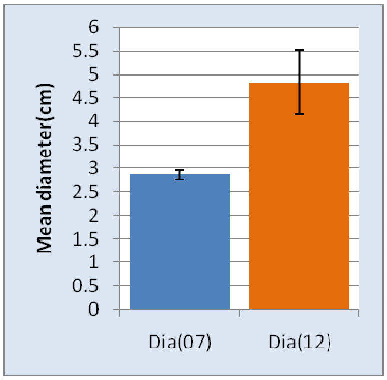


Fig.5. Mean height growth of *P. chinensis*. *(Debre Zeit)*

Fig.6 Mean diameter growth of *P. chinensis*. *(Debre Zeit)*

Error bars are SEM with n=3.Ht(07): height in 2007.Ht(12):height in 2012.Dia(07):Diameter in 2007.Dia(2012): Diameter in 2012.

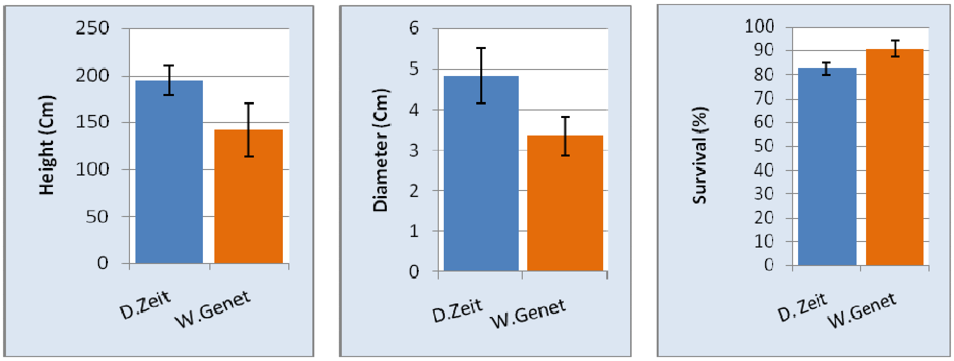


Fig.7. Growth performance of *P. chinensis* across locations.

Error bars are SEM with n=3.

Fig.8. Six years old Pistacia at Debre Zeit

Fig.9. Six years old Pistacia at Wondo Genet

Discussion:

P. chinensis is virtually unknown all over Ethiopia in spite of its extensive value as root stock for the commonly known nut bearing Pistacia among commercial nut producers of Europe and Middle East. Except a few introduced mother trees in the premises of Debre Zeit Agricultural Research Center, the wide potential of the species as a metropolitan tree and root stock for nut bearing *Pistacia vera* has not so far been experimentally evaluated under Ethiopian conditions. Observation trials on germinations of the species under the nursery soil mixes of Debre zeit agricultural Research Center revealed very low percentages (mostly below 25%). This initiated the need to experiment on different substrate mixes and sowing methods that would enhance the germination to an acceptable percentage for nursery production. The growth performance and field adaptive potential of the species is also little known. In addition, establishment of *Pistacia chinensis* stands for future vegetative propagation of *Pistacia vera* scions is a forestry activity that has not been looked into before. The aim of this study was to make a step towards addressing the above mentioned research questions. The achievement of a good rooting system is a very important characteristic and vigor is a desirable character in pistachio rootstocks (Vergas et al 1998). *P. chinensis* has been reported to be a potential root stock for nut bearing *Pistacia vera* though it is susceptible to severe cold in winter. However, this is not the case with the adaptation trial in this study for prolonged winter colds are not peculiar characteristics of the study areas. Mean comparisons of germination percentages in the nursery propagation study revealed highly significant differences between the treatment (Farm yard manure) and control (Standard soil mixture) groups at $P<0.05$ where in both cases seeds of the species were sown without removing their pods. This signified that sowing seeds of *P. chinensis* with pods on farm yard manure gives significantly better germination percentage averaging to 51.55% (at $p<0.05$) than doing it so on standard soil mixtures that averaged 35.7%. This could partly be attributed to the coarse textured nature of FYM to facilitate emergence and prolongation of the essential seedling structures. Yet pretreatment techniques like scarification of seed before sowing ought to be tried out to better enhance the germination percentage than what is acquired through cold water treatment and varying substrate conditions as above. In addition, mean comparisons of germination percentages on SSM revealed a highly significant decline in germination of seeds sown without pods versus the control groups, i.e. seeds sown with pods at $P<0.05$. Thus, it can be concluded that removal of seed pods is not advisable to propagate Pistacia in the nursery. In relation to the field performance evaluation of the species mean comparisons of height and diameter growth showed significant differences between two and six years after planting at $P<0.05$ for Debre Zeit location. This was revealed by a mean height and diameter of 194.61cm and 4.82 cm, respectively, in six years while the averaged counterparts in two years were 99.1cm and 2.8 cm for Debre Zeit location. Across location data on height, diameter and survival of trees were also subjected to statistical analysis. Ac cordingly, height and diameter performance of the tree species was significantly higher at Debre Zeit than Wondo Genet based on the comparison of error bars. In contrast, across location survival percentages revealed no significant differences after six years of planting. Thus, for future out planting on large scale basis for either road side or plantation, Debre Zeit is relatively preferred over Wondo Genet for the trial revealed highly significant height and diameter growth and a comparable survival rate at Debre Zeit than Wondo Genet. The species is endowed with its highly desirable characteristics like high drought tolerance, capability to thrive under poor soil conditions, radiance and beauty of the leaf under full sun conditions and less likelihood of being browsed by cattle. *Pistacia chinensis* is presently under rigorous popularization program for beautifying the city of Debre Zeit.

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