

Tea oil camellia plantation, an enormous potentiality for poverty reduction

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ABSTRACT

Aims: Apply different silvicultural approaches to improve oil productivity and quality from abandoned stands and analyze benefit-cost of developing tea oil camellias.

Study design: Three experiments were conducted as (1) Changing canopy of 36-year-old plantation by grafting, (2) Using Bortrac fertilizer for promoting fruiting by spraying to canopy, and (3) Stem/branch thinning and fertilizing.

Place: North Central, Vietnam at 19°16'N and 105°23'E.

Methodology: Shoots of 4 – 6 mm in diameter and 3 -5 cm long from improved cultivar were used to graft to 36-year-old trees. Bortrac fertilizer was used to spray to canopy of 15-year-old plantation when trees bloomed. While three treatments of stem/branch thinning and fertilizing at different intensities were applied to 29-year-old plantation of 830 trees ha⁻¹.

Results: The results showed that old stand, which has low seed productivity, could be replaced by a new canopy through grafting with improved cultivars. Meanwhile, fertilizing through spraying on canopy at early blooming peak with Bortrac fertilizer increased productivity 28%. In addition, applying 0.5 kg NPK and 5 kg organic manure per tree coupled with thinning under crown-old branches and diseased branches may increase up to 60% productivity and improve oil ratio and quality.

Conclusion: There is a potentiality in poverty reduction by growing tea oil camellia as the high net income of 2,426 USD ha⁻¹ year⁻¹ for 29-year-old plantation, much higher than other agricultural and forestry activities.

Keywords: Cost-benefit analysis; market instability; productivity; silvicultural approaches; tea oil camellia.

1. INTRODUCTION

Camellia sasanqua Thunb., tea oil camellia, naturally distributes from Southwestern Japan [1] to Korea, Nepal, and Southeast Asian regions [2]. In Vietnam, this species was found in northern provinces from 17° – 23°21'N on elevation zone under 1,780m [3]. The camellia tea oil has been widely used in China for cooking oil, ink, lubricant and cosmetic [4], and some local areas in Vietnam for cooking oil [5]. After extracting oil the residual, seedcake, can be used for animal feed, fertilizer or bio-pesticides [6]. Because of high values of oil and residual, tea oil camellia has been planted in Southeastern United States since 2001 and shown promising for large-scaled plantation [6, 7].

Despite the long history of extensive planting and use of tea oil camellias, its productivity and quality remain low [8, 9, 10], leading to low income of growers who are classified as poor or

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very poor households in Vietnam. Techniques supports toward intensive planting tea oil camellias are required for income improvement and poverty reduction. Currently, there are around 6,000 ha of tea oil camellia, which are under high age classes and low oil productivity of under 500 kg ha⁻¹ year⁻¹ [8] compared to higher than 1,000 kg ha⁻¹ year⁻¹ of intensive tea oil camellia plantation in China [11]. In addition, the demand for camellia tea oil in the world has been increasing in recent years due to its high quality [6] and antioxidant capacity [12]. Therefore, besides enlarging areas by using improved cultivars, intensive silvicultural approaches should be considered and applied to current available planted areas for enhancing productivity and income of growers. This paper addressed silvicultural approaches in terms of (1) changing canopy of 36-year-old plantation by grafting, (2) using Bortrac fertilizer for promoting fruiting by spraying to canopy, (3) stem/ branch thinning and fertilizing for improving oil productivity and quality, and (4) cost-benefit analysis for applied silvicultural approaches in tea oil camellia plantation in north Central of Vietnam.

2. MATERIAL AND METHODS

2.1 Study Site

Tea oil camellia has been widely planted in north Vietnam, however it is much focused in north Central at 19°16'N and 105°23'E, where this study was carried out. The study site was located in hilly areas in elevation zone under 100 m above sea level. Monsoon climate dominates in this area with four distinct seasons. The rainy season is from August to October and dry season is between April and June with annual precipitation of 2,055 mm. There is annual mean temperature of 25.1°C, maximum of 41.6°C, and minimum of -0.2°C [13]. Feralitic is a dominant soil type, characterized as loam and sandy loam, depth of up to 1.2 m, pH of 3.5-4.0, and organic matter of 2.5-3.0%. In general, such conditions are suitable for growing tea oil camellia [8]. There are approximate 1,100 ha tea oil camellia plantations in study site, which range from 4 to 45 years old.

2.2 Experiments

2.2.1 Changing canopy of 36-year-old plantation by grafting

Two hundred thirty trees of *C. sasanqua* in 36-year-old plantation were selected. All trees were cut at 0.8-1.0 m above ground. After six months shooting, only two or three best shoots from a cut stump were selected for grafting, others were removed. Grafted shoots were collected from clone NA15, which was tested for high oil productivity and quality in the same study site [14]. Grafting was carried out in November, 2006. Shoots from stumps were cut at 8-10 cm. Grafted shoots with at least two buds taken from improved cultivar – NA15, having the same diameter (4-6 mm) with shoots from cut stumps, were selected for grafting. Grafted shoots were cut to 3-5 cm long, removed all leaves, then were grafted to shoots of cut stumps. Finally, conjunction between two shoots was covered by nylon. When buds from grafted shoots appeared, the nylon was removed.

The data were collected regularly at 9, 18, 24, 30, 36, 48, 72 months after grafting, including survival, D_o (diameter of grafted shoots at 8 – 10 cm from grafting point), shoot length (L), and D_c (crown diameter of grafted shoots). Observation of flowering and fruiting, and number and weight of fruits in each grafted shoot were also carried out.

2.2.2 Using Bortrac fertilizer for promoting fruiting by spraying to canopy

Twenty ml Bortrac fertilizer was mixed with eight liter of ordinary water, then the mixture was sprayed to canopy of 15-year-old plantation when blooming was at early peak in November,

2006. Ripened fruits were collected in November, 2007 from sprayed plots and control plots (no spraying) for comparison.

2.2.3 Stem/ branch thinning and fertilizing

This experiment was carried out in 29-year-old plantation of 830 stumps/ ha. There were three treatments as following: BTF1 – fertilizing 0.5 kg NPK (5:10:3) per stump and thinning stems [in general, many stems (up to 12 stems) grow from a stump in *C. sasanqua* tree]; BTF2 – fertilizing 1 kg NPK per stump and thinning branches; BTF3 – fertilizing 0.5 kg NPK and 5 kg organic manure per stump, and thinning branches; and Control (no thinning and fertilizing).

For each stump, 25% of stems were thinned in BTF1. Meanwhile, in BTF2 and BTF3 old branches at low crown position and diseased branches were thinned to improve light penetrating to remained branches. Branch and stem thinning was carried out in 1998, while fertilizing was applied in three consecutive years of 1998-2000 one per year in February - March when flower buds are initiated for the following year fruiting [13]. Fruit productivity was collected in five year duration between 1998 and 2002. Seeds were separated from collected fruits and dried in room conditions for dry mass. Samples of dry seeds were used to estimate kernel ratio and then oil/ kernel ratio by traditional extracting method as air-dry for 4-5 days (direct to sunshine), steaming, and squeezing for oil. Oil chemicals including protein, C.S.Iod, and potassium hydroxide were also identified by Soxhlet method.

2.3 Cost-benefit Analysis (CBA)

CBA was applied for stem/ branch thinning and fertilizing treatment. Costs covered for fertilizer and labor of thinning, fertilizing, and seed collecting. Benefit covered income from selling dry seed, seedcake (residual after extracting oil) and oil, which was extracted by traditional method. Other benefits such as fuel, recreation, environment service *etc.* were not included since there were no prices tagged.

Since the data about price of dry seed, oil, seedcake, NPK, and organic manure before 2002 were not available, then price in 2012 was used for CBA. One kg NPK (5:10:3) cost 0.25 U\$D, organic manure cost 0.033 U\$D kg⁻¹, dry seed cost 0.6 U\$D kg⁻¹, oil cost 2.9 U\$D liter⁻¹, a labor day cost 6 U\$D, and one ton seedcake cost 500 U\$D. All prices were based on local markets. The interest rate (*IR*) of 3% was used for calculation. Then present values (*PV*) of costs or benefits were calculated following equation 1.

$$PV = \sum_{i=1}^t \frac{PastV_i}{(1 + IR_i)^t} \quad (1)$$

where, V_i is past values of cost or benefit and t is number of years from year i (from 1998) to present (2002). We calculated for five year duration as period of experiment of stem/ branch thinning and fertilizing (1998-2002).

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Changing canopy of 36-year-old plantation by grafting

Survival rate was 63% after two months grafting, then it decreased to 54% after 4 years as a result of clear cutting crown of all trees in plots leading to water inefficiency, and death of

some cut stumps. After four years, mortality was nearly zero as result of robust grafted shoots, which were later affected by harsh environment.

Diameter (D_o) grew quite slowly in the first 18 months, then facilitated to reach 2.6 cm at 30 months and upto 4.9 cm at 72 months. Meanwhile, growth patterns of shoot length (L) and shoot crown diameter (D_c) were much more smoother in the first 72 months (Fig. 1). The shoot length and D_c reached to 3.4 and 2.6 m at 72 months, respectively.

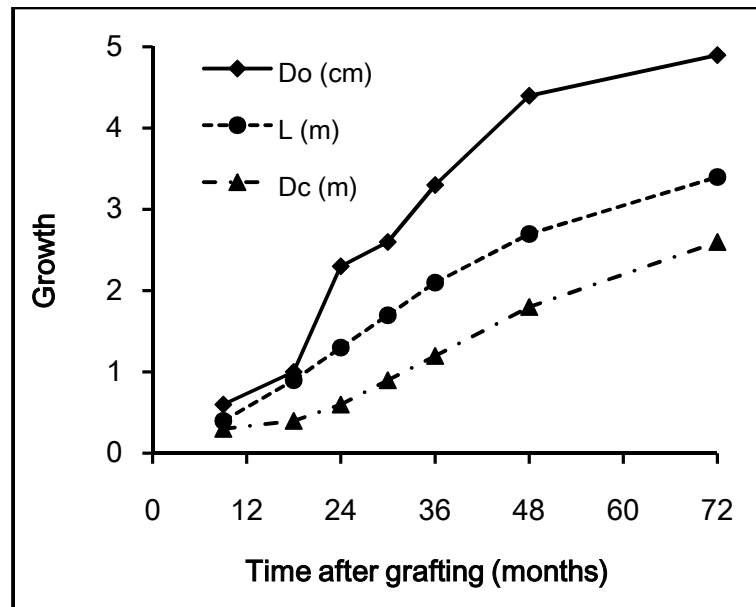


Fig 1: Growth of grafted shoots

After grafting 3 years, 92% grafted shoots bloomed. In which 86% fruited, then increased to 89% in the fourth year. In the sixth year, each grafted shoots owned approximately 0.5 kg fruits in average. In general, there were not much differences of fruit and seed parameters between grafted shoots and mother trees by *t*-test at 5% confidence (Table 1). This may indicate that grafted stumps are still good enough to support grafted shoots in water and nutrient uptake.

Table 1: Comparison of fruit and seed parameters between grafted shoots and mother trees

	Fruit		Seed		Mean seeds/ fruit	Seed/ fruit ratio (%)
	Diameter	Length	Diameter	Length		
Grafted shoots	2.9	3.0	1.6	2.0	3.4	58.7
Mother trees ¹	2.7	2.7	1.5	1.9	3.3	59.5

¹ trees used to get shoots for grafting, improved cultivar NA15.

3.1.2 Using Bortrac fertilizer for promoting fruiting by spraying to canopy

It clearly showed that using Bortrac fertilizer to spray on canopy at early blooming peak significantly increased productivity of 15-year-old *C. sasanqua* plantation to 427 kg ha⁻¹ compared to 333 kg ha⁻¹ of control (Fig. 2), equal to productivity increase of 28%.

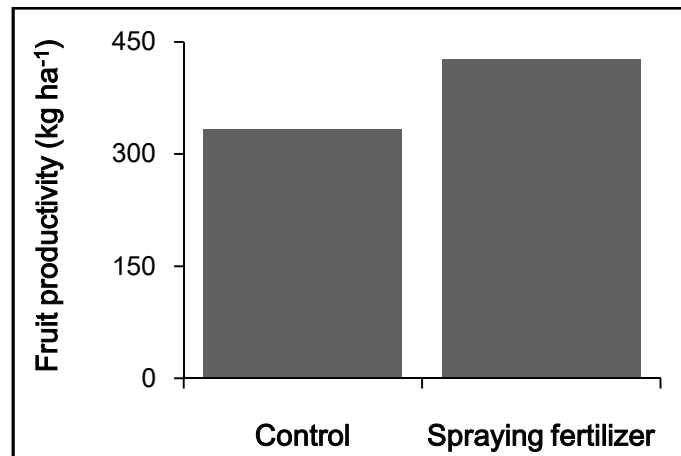


Fig 2: Effect of fertilizer spraying on fruit productivity

3.1.3 Stem/ branch thinning and fertilizing

BTF3 resulted in highest dry seed productivity as 3,071 kg ha⁻¹ at year 2002, following were BTF2 (2,822 kg ha⁻¹) and BTF1 (2,324 kg ha⁻¹). The productivity increased gradually after treatment (Fig. 3a). Five years after treatment, productivity increased 85, 62, and 40% for BTF3, BTF2, and BTF1 compared to that before treated treatment (year 1998), respectively. Comparing to productivity of control at the same observation year, that of other three treatments were much higher. The highest differences happened in year 2001 at 75, 50, and 35% for BTF3, BTF2 and BTF1, respectively, then the same order but decreasing in year 2002 (Fig. 3b).

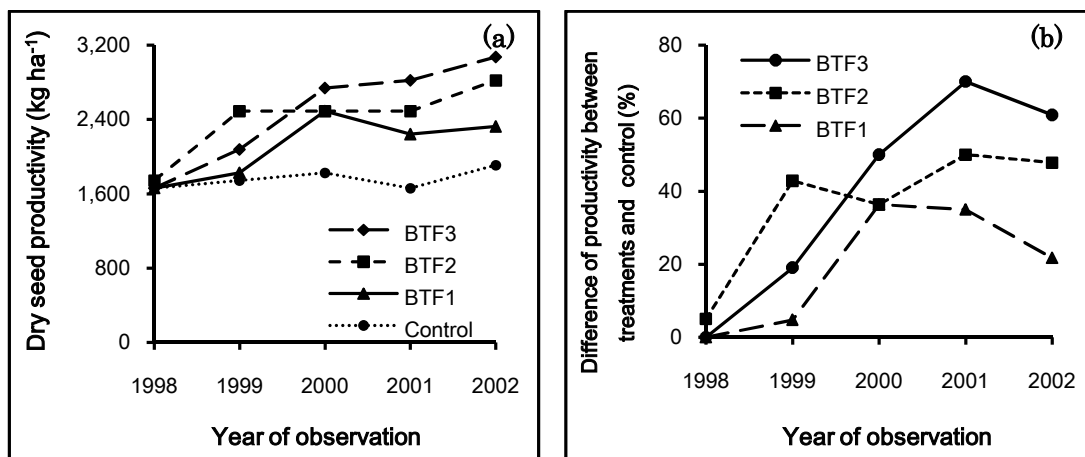


Fig 3: Effects of stem/ branch thinning and fertilizing on dry seed productivity of *C. sasanqua* plantation. (BTF1 – fertilizing 0.5 kg NPK (5:10:3) per stump and thinning stems; BTF2 – fertilizing 1 kg NPK per stump and thinning branches; BTF3 – fertilizing 0.5 kg NPK and 5 kg organic manure per stump, and thinning branches; Control (no thinning and fertilizing)

Kernel ratio in three treatments was significantly higher than that in control (Table 2), meanwhile oil/ kernel ratio was higher in BTF3 and BTF2 compared to that in BTF1 and control. Others parameters such as protein, C.S Iod, and potassium hydroxide were

generally higher in treatments than in control but not significant (Table 2). Oil density was not affected by treatments.

Table 2: Effect of treatments on characteristics of seed and oil

Treatment	Seed cover (%)	Kernel (%)	Oil/ kernel (%)	Protein (%)	C.S Iod (gI ₂ /100 g oil)	Potassium hydroxide (mg/1 g oil)	Density (kg/L)
BTF1	34.6	65.4 ^a	48.9 ^b	6.4 ^a	82.1	190.0	0.92
BTF2	34.7	65.3 ^a	50.0 ^a	6.0 ^a	82.3	189.5	0.92
BTF3	34.4	65.6 ^a	50.5 ^a	4.1 ^b	80.1	188.0	0.92
Control	35.2	64.6 ^b	48.6 ^b	5.9 ^a	80.1	189.0	0.92

Different letters in a column indicate significant difference between treatments by *t*-test at 5% confidence.

3.1.4 Cost-benefit analysis

Most families sold dry seeds as final product. The annual net income of 29-year-old tea oil camellia plantation decreased in order of BTF2, BTF3, BTF1, and control as 549, 530, 517, and 502 USD ha⁻¹, respectively (Table 3). Meanwhile, some families with large-planted areas extracted oil as final product for selling in local market. They may get higher net income as 1,791 USD ha⁻¹ year⁻¹ for not applying silvicultural techniques. If applying treatment as stem/ branch thinning and fertilizing, annual net income may increase to 2,082 USD ha⁻¹ using treatment BTF1, to 2,374 USD ha⁻¹ in treatment BTF2, and to 2,426 USD ha⁻¹ in treatment BTF3 (Table 3). There was not much difference of annual net income, only 3%, between BTF3 and BTF2. While, it was much different between BTF2 and BTF1 (16%; Table 3).

Table 3: Cost and annual net income (USD ha⁻¹) from five-year-stem/ branch thinning and fertilizing treatment

		BTF3	BTF2	BTF1	Control
Oil as final product	Present value of five year cost for fertilizer ¹	713	518	259	
	Present value of five year cost for labor ²	1,754	1,717	1,528	1,119
	Present value of five year benefit for oil ³	12,489	12,031	10,336	8,520
	Present value of five year benefit for seedcake ⁴	2,111	2,076	1,860	1,554
	Annual net income	2,426	2,374	2,082	1,791
	Annual income including labor cost	2,777	2,718	2,387	2,015
	Increase compared to control (%)	37.8	34.9	18.5	
Dry seeds as final product ⁵	Present value of five year benefit for dry seeds	5,117	4,980	4,370	3,627
	Annual net income	530	549	517	502
	Annual income including labor cost	881	892	822	725
	Increase compared to control (%)	21.4	23.0	13.3	

¹0.25 USD kg⁻¹ NPK (5:10:3) and 0.033 USD kg⁻¹ organic manure; ²6 USD labor day⁻¹; ³2.9 USD litter⁻¹ oil; ⁴0.5 USD kg⁻¹ seedcake; ⁵0.6 USD kg⁻¹ dry seed.

3.2 Discussion

3.2.1 Silvicultural approach

Clone NA15, which was used in grafting treatment, is the best clone selected in the study site. This 40-year-old tree had productivity of 11.8 kg dry seed year⁻¹ (56.2% higher than mean of stand; [14]). In addition, *C. sasanqua* plantation established from seedlings is generally getting stability of productivity at 12-15-year old [8]. It is predicted that grafted stand may get stability of productivity of 9,794 kg dry seed ha⁻¹ year⁻¹ after 7 years grafting [13]. However, this treatment is in initial stage (Fig. 1), therefore much attention should be given to disease control, longevity of grafted shoots, water and nutrient uptake ability of grafted stumps etc.

Effects of fertilizer application and timing have been widely studied for fruit trees like apple [15], pecan [16, 17], and red raspberry [18]. In this study, doses applied were much focused than timing. It indicated that increasing dose, generally, increased productivity, the same conclusion for *C. oleifera* plantation in China [19-21]. Meanwhile, type of fertilizers had also much affected. Organic manure showed better than inorganic fertilizer (NPK). This may result from the fact that tea oil camellia could not uptake all applied NPK in short time, then much was lost from uptake by other plants or leaching. While, organic manure decomposed gradually to release nutrient for *C. sasanqua* tree uptake in longtime. Fertilizer was applied in February - March every year to initiate flower buds for the following year, such researches were also carried out for deciduous fruit trees like nectarine and apple [22, 23]. However, tea oil camellia *C. sasanqua* is an evergreen tree, which may grow throughout the year. Therefore, other researches on application timing may be necessary, for example immediately after blooming, fruiting, or a month before ripening to increase oil ratio and quality.

Bortrac fertilizer showed promising in enhancing fruiting of *C. sasanqua* plantation (Fig. 2), however timing of application may also be important and need to be confirmed in the following researches [23]. If two treatments as using Bortrac fertilizer and BTF3 (fertilizing 0.5 kg NPK and 5 kg organic manure per stump, and thinning branches; Fig. 3) are combined, the dry seed productivity may increase to 3,930 kg ha⁻¹ year⁻¹ (Fig. 2, 3), doubling productivity of no treatment (control). However, when productivity increases, more fertilizing may be required to support blooming and fruiting, and to keep characteristics of fruits and seeds stable (Table 2).

3.2.2 Cost-benefit analysis

For residents living in local areas, generally their income always includes the cost of their own labor. Therefore, income from tea oil camellia plantation may increase up to 2,777 USD ha⁻¹ year⁻¹ if they apply treatment BTF3 and use traditional techniques for extracting oil (Table 3). While, it decreases to very low as 892 ha⁻¹ year⁻¹ for applying treatment BTF2 and selling final product as dry seeds (Table 3). All growers can extract oil themselves, however most families sell dry seeds other than oil, because of instability of local market. If they all extract and sell oil as final product, then price may fall down since there are not so many consumers. Even quite high annual net income from old plantation of *C. sasanqua* (Table 3), large areas of tea oil camellia plantation have been abandoned in Vietnam, because of uncertainty in oil quality as extracted by traditional methods leading to instability of market. In addition, tea oil camellia had been planted in the past solely based on individual grower's decision other than a development program managed by Government, leading to small-scaled areas of less than 0.4-0.5 ha per family. Therefore, new technology in oil extracting

has not been applied other than traditional one, which is cheap and requires no techniques for application by all growers.

Market for camellia oil is only focusing on local citizens, where trees have been growing. The product has never been found in super market, because quality control and bottling have not yet been done. Such stories had been recognized by tea oil camellia growers, then “A National Program on Development of Oil Plants” was launched in 2004 [24]. However, since then not much attention has been given to tea oil camellias other than peanut, soybean, coconut. Traditionally, Vietnamese consumers prefer using peanut, soybean, and coconut oil other than tea oil, even price of tea oil is much lower [5] because of less information availability on camellia tea oil. It is obvious that mountainous land areas which suitable for planting tea oil camellias are abundant, while land areas for planting other plant oils as peanut, soybean, and coconut are limited. Therefore, developing tea oil camellias in mountainous areas is probably the best choice to help farmers improving income and reducing poverty sustainably.

It is clear that, even being able for high benefit, tea oil camellias will never become important oil tree in reducing poverty, if there is no urgent actions from Government such as a propaganda for camellia tea oil in country nationwide, advanced technology in oil extracting and quality control, and high productivity cultivar selection. Therefore, a national program on development of tea oil camellias focusing on above-mentioned issues should be soon considered and put into action, which is expectation of growers for tea oil camellia development, income improvement, and poverty reduction.

4. CONCLUSION

Three silvicultural applications have shown promising in improving productivity of tea oil camellia plantation in north Central of Vietnam. In which, changing canopy by grafting improved cultivar will result in a much better plantation after 6-7 years as it increased seed productivity relative to that of improved cultivar. Bortrac fertilizer application through spraying on canopy at early blooming peak showed 28% productivity higher than no spraying. Thinning under crown and old branches and diseased branches with fertilizing 0.5 kg NPK (5:10:3) and 5 kg organic manure per stump resulted in highest productivity as 3.070 kg dry seeds year⁻¹, equal to net income of 2,426 USD ha⁻¹ year⁻¹. If a four-person household owns a hectare of tea oil camellias and applies the best intensive techniques, annual income of 2,426 USD is high enough to lead them out of poor/very poor household classification. However, initial financial and technical supports from Government for establishing tea oil camellias plantation are required.

Small-scaled planted areas and instability of market are two biggest issues in developing tea oil camellia in Vietnam. The problems can only be solved by actions of Government other than growers themselves. Therefore, a more intensive study on tea oil plantation to help solve small-scaled planted areas and market instability should be conducted in soon future.

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311 **COMPETING INTERESTS**

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313 Authors have declared that no competing interests exist.

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