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# Tea Oil Camellia Plantation, an Enormous Potentiality for Poverty Reduction

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author HVT designed the study, and wrote the protocol. Author TVD performed the statistical analysis, wrote the first draft of the manuscript and managed the literature searches. Author TS managed the literature searches and commented to manuscript. Author NQK designed the study and identified the species of plant. All authors read and approved the final manuscript.*

***Original Research Article***

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## ABSTRACT

**Aims:** Apply different silvicultural approaches to improve oil productivity and quality from abandoned stands and analyze cost-benefit 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 19º16'N and 105º23'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 was 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 seed

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productivity by 28%. In addition, applying 0.5 kg inorganic fertilizer (NPK) and 5 kg organic manure per tree coupled with thinning under crown-old branches and diseased branches increased up to 60% seed productivity and improved oil ratio and quality. Cost-benefit analysis indicated that by applying different intensities of stem/branch thinning and fertilizing to 29-year-old plantation, profit margin increased from US$ 502 to as much as US$ 549 $ha^{-1}$ $year^{-1}$ for growers selling dry seeds as final product. Meanwhile, it increased from US$ 1,791 to US$ 2,426 $ha^{-1}$ $year^{-1}$ by extracting oil for final product.

**Conclusion:** There is a potentiality of growing tea oil camellia with the increased profit of as much as US$ 2,426 $ha^{-1}$ $year^{-1}$ for 29-year-old plantation by applying intensive silvicultural approach.

*Keywords: Cost-benefit analysis; market instability; productivity; silvicultural approach; 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 17º – 23º21'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 in some local areas of 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 very poor households in Vietnam. Technical 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 camellias, which are low oil productivity of under 500 kg $ha^{-1}$ $year^{-1}$ [8]. Meanwhile, oil productivity of intensive tea oil camellia plantations in China is found to have been as high as 1,000 kg $ha^{-1}$ $year^{-1}$ [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 on (1) impacts of applying intensive silvicultural approaches on seed productivity and oil quality and (2) analyzing cost-benefit for applied silvicultural approach in tea oil camellia plantation in north Central of Vietnam.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

This study was conducted in north Central, Vietnam at $19^0 16'$N and $105^0 23'$E (Nghia Dan District, Nghe an Province), where more than 50% areas of tea oil camellia plantation are distributed. In addition, growers in Nghe An District are classified as poor households and their life is much depending on income from tea oil camellias plantation. 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 25.1ºC, maximum of 41.6ºC, and minimum of -0,2ºC [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 camellias [8]. There are approximate 1,100 ha tea oil camellia plantations in study site, which range from 4 to 45 years old.

## 2.2 Description of Tea Oil Camellia Tree

*Camellia sasanqua* Thunb. belonging to Theaceae is an evergreen and small-sized tree. It may grow up to 9 m at maturity. Generally, there are 6-12 stems growing from a stump. Planted *C. sasanqua* tree starts blooming at 5 years old, however it fruits stably from the age of 12 years. Flowers bloom in October-November and fruits ripen in October-November of the following year. Depending on soil condition and tending activities, *C. sasanqua* plantation may gradually reduce its productivity after 70 years old, while its longevity is up to 120 years. Generally, there is a 2-year rotation of high productivity. It is known that low productivity year is time for trees to uptake and store nutrient and energy for the following year/high productivity year.

## 2.3 Experiments

There were three experiments conducted in this study. Each experiment was conducted in different plantation of different age, at different time, and for different purposes. The different times of experiment were simply because of budget allocation from donor, even conducting all experiments in the same time is technically well known for better results and comparison. This is the limitation of this experiment.

### 2.3.1 Changing canopy of 36-year-old plantation by grafting

A 36-year-old plantation of a household including 230 trees of *C. sasanqua* were selected. Only one household was selected because of its willingness to participate in this experiment. Since persuading households in conducting a new experiment, whose results was not clear, was not easy work. 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. This experiment was conducted in six consecutive years (November, 2006 - November, 2012).

### 2.3.2 Using Bortrac fertilizer for promoting fruiting by spraying to canopy

Basing on manual for using Bortrac fertilizer, 20 ml was mixed with eight litter 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. This experiment was conducted in one year (November, 2006 – November, 2007), which belonged to low productivity year.

### 2.3.3 Stem/ branch thinning and fertilizing (BTF)

This experiment was carried out in 29-year-old plantation of 830 stumps ha$^{-1}$. There were three treatments as following: BTF1 – fertilizing 0.5 kg NPK (Nitrogen : Phosphor : Potash/ 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 were 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 indentified by Soxhlet method.

## 2.4 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. Profit covered income from selling dry seed, seedcake (residual after extracting oil) and oil, which was extracted by traditional method. Other profits 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 US$ 0.25, organic manure cost US$ 0.033 kg$^{-1}$, dry seed cost US$ 0.6 kg$^{-1}$, oil cost US$ 2.9 litter$^{-1}$, a labor day cost US$ 6, and one ton seedcake cost US$ 500. All prices were based on local markets. The interest rate (*IR*) of 3% was used for calculation. Then present values (*PV*) of costs or profits were calculated following equation 1.

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

where, $V_i$ is past values of cost or profit 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

### 3.1 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 not much 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 up to 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.

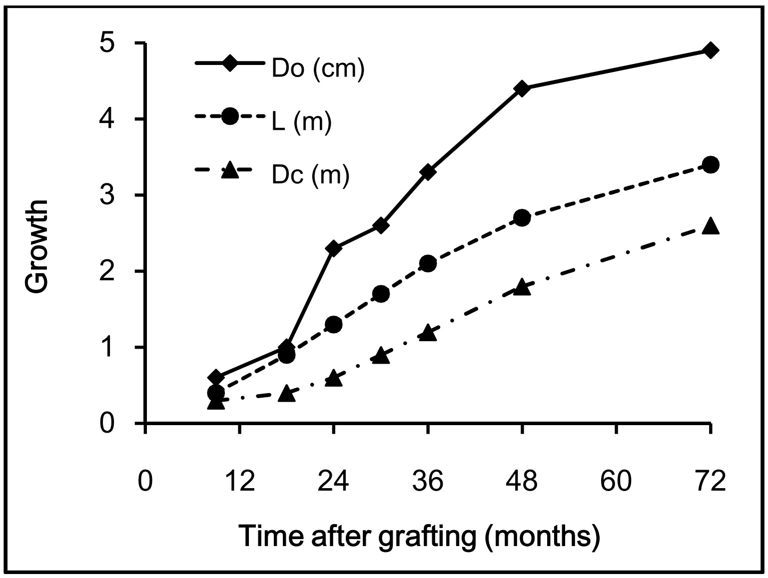


**Fig. 1. Growth of grafted shoots**

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 $p$ = 0.05 (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 | Seed/ fruit |
|---|---|---|---|---|---|---|
| | Diameter | Length | Diameter | Length | seeds/ fruit | ratio (%) |
| 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.*

### 3.2 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 (*t*-test at $p = 0.05$) increased seed 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%.

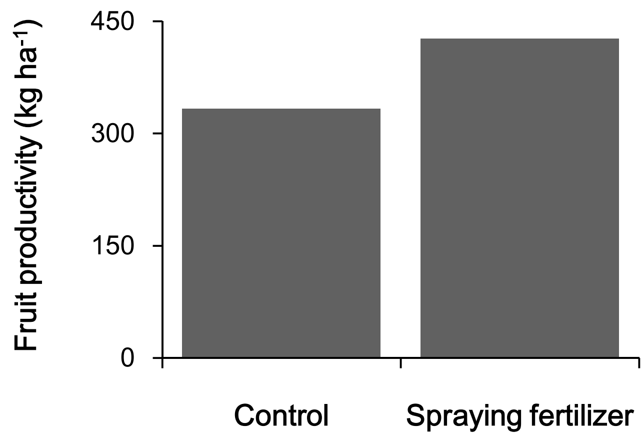


**Fig. 2. Effect of Bortrac fertilizer spraying on fruit productivity**

## 3.3 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 seed productivity increased gradually after treatment (Fig. 3a). Five years after treatment, seed 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).

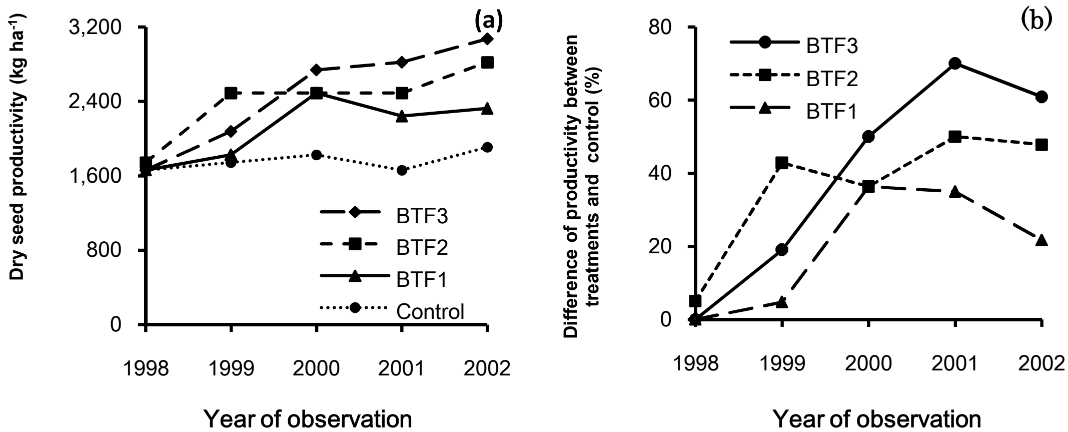


**Fig. 3. Effects of stem/ branch thinning and fertilizing on dry seed productivity of *C. sasanqua* plantation. BTF1 – fertilizing 0.5 kg NPK (5:10:3) per stump and thinning stems; BTF2 – fertilizing 1 kg NPK per stump and thinning branches; BTF3 – fertilizing 0.5 kg NPK and 5 kg organic manure per 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 p = 0.05.*

## 3.4 Cost-benefit Analysis

Most families sold dry seeds as final product. The annual profit of 29-year-old tea oil camellia plantation decreased in order of BTF2, BTF3, BTF1, and control as 549, 530, 517, and US$ 502 ha$^{-1}$, respectively (Table 3). Some families with large-planted areas extracted oil as final product for selling in local market, leading to profit of US$ 1,791 ha$^{-1}$ year$^{-1}$ for growers not applying silvicultural techniques. By applying treatment as stem/ branch thinning and fertilizing, annual profit increased to US$ 2,082 ha$^{-1}$ using treatment BTF1, to US$ 2,374 ha$^{-1}$ in treatment BTF2, and to US$$^{-1}$ 2,426 ha in treatment BTF3 (Table 3). There was not much difference of annual profit, only 3%, between BTF3 and BTF2. While, it was much different between BTF2 and BTF1 (16% annual profit; Table 3). Annual income which included cost for labor increased from US$ 881 $ha^{-1}$ by using dry seed as final product to US$ 2,777 $ha^{-1}$ by using oil as final product in treatment BTF3 (Table 3).

**Table 3. Costs, annual profit, and annual income (US$ $ha^{-1}$) from a five year experiment of stem/ branch thinning and fertilizing applied for 29-year-old *C. sasanqua* plantation**

| | | BTF3 | BTF2 | BTF1 | Control |
|---|---|---|---|---|---|
| | Present value of five year cost for fertilizer (FC)[1] | 713 | 518 | 259 | |
| | Present value of five year cost for labor (LC)[2] | 1,754 | 1,717 | 1,528 | 1,119 |
| Oil as final product | Present value of five year for oil (PO)[3] | 12,489 | 12,031 | 10,336 | 8,520 |
| | Present value of five year for seedcake (PC)[4] | 2,111 | 2,076 | 1,860 | 1,554 |
| | Annual profit (APO) | 2,426 | 2,374 | 2,082 | 1,791 |
| | Annual income (AIO) | 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 for dry seeds (PS) | 5,117 | 4,980 | 4,370 | 3,627 |
| | Annual profit (APS) | 530 | 549 | 517 | 502 |
| | Annual income (AIS) | 881 | 892 | 822 | 725 |
| | Increase compared to control (%) | 21.4 | 23.0 | 13.3 | |

*[1]US$ 0.25 $kg^{-1}$ NPK (5:10:3) and US$ 0.033 $kg^{-1}$ organic manure; [2]US$ 6 labor $day^{-1}$; [3]US$ 2.9$litter^{-1}$ oil; [4]US$ 0.5 $kg^{-1}$ seedcake; [5]US$ 0.6 $kg^{-1}$ dry seed. APO = [(PO + PC) – (FC+LC)]/5; AIO = [(PO + PC) – FC]/5; APS = [PS – (FC+LC)]/5; AIS = [PS – FC]/5.*

## 4. DISCUSSION

### 4.1 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 seeds $year^{-1}$ (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 seeds $ha^{-1}$ $year^{-1}$ after 7 years grafting [13].

Effects of fertilizer application and timing have been widely studied for fruit trees like apple [15], pecan [16,17], and red raspberry [18]. It indicated that increasing amount of applied fertilizer, 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 braches; Fig. 3) are combined, the dry seed productivity may increase to 3,930 kg ha$^{-1}$ year$^{-1}$ (Figs. 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).

## 4.2 Cost-benefit Analysis (CBA)

There were three experiments in this study, however only "stem/ branch thinning and fertilizing – BTF" experiment was used for CBA. Because this 5-year experiment was conducted in 29-year-old plantation, which fruited stably. The overhead costs are not available, since plantation was established 29 years ago by growers themselves and they did not intend to remember the costs they had to pay. Therefore, in CBA only costs (fertilizer and labor costs) for conducting BTF experiment were included. The fact was that growers were going to abandon their plantations because of low seed productivity and oil quality, therefore we would like to prove them that by applying suitable silvicultural approach as BTF of different intensities their income will be improved by continuing tending/ maintaining plantations. Two values were estimated in this study including annual profit as net profit after extracting fertilizer and labor costs, and annual income as gross income after extracting only fertilizer costs. For residents living in local areas and local government, annual income (including labor cost itself; Table 3) is much more interested than annual profit. Therefore, income from tea oil camellia plantation increases up to US$ 2,777 ha$^{-1}$ year$^{-1}$ for growers applying treatment BTF3 and use traditional techniques for extracting oil (Table 3). While, it decreases to very low as US$ 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 households sell dry seeds other than oil, because of instability of local market. If they all extract and sell oil as final product, then price falls down since there are not so many consumers. Even high annual profit (US$ 2,426 ha$^{-1}$) from 29-year-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 requires low cost for extracting equipment and simple 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, and coconut. Traditionally, Vietnamese consumers prefer using peanut, soybean, and coconut oil other than tea oil, even prize of tea oil is much lower [5] because of less information availability on camellia tea oil. It is obvious that mountainous land areas 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.

It is clear that, even being able for high profit, tea oil camellias will never become important oil tree in reducing poverty, if there is no urgent actions from Government such as advanced technology in oil extracting and quality control, and high productivity cultivar selection.

## 5. CONCLUSIONS

Three silvicultural approaches have shown promising in improving productivity of tea oil camellia plantation in north Central of Vietnam. In which, changing canopy by grafting improved cultivar resulted 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, old, 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 ha $^{-1}$ year$^{-1}$, equal to profit of US$ 2,426 ha$^{-1}$ year$^{-1}$. While, selling dry seeds as final product reduced 75% of profit compared to oil selling (from US$ 530 to US$ 2,426 ha$^{-1}$ year$^{-1}$ in BTF3 treatment).

## RECOMMENDATION

Small-scaled planted areas and instability of oil 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 national program on development of tea oil camellias focusing on above-mentioned issues should be soon considered and put into action. To ensure the success of program, a more intensive study on tea oil plantation should be conducted in soon future. In addition, initial financial and technical supports from Government for establishing tea oil camellia plantation are required for growers.

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### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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