Yield and essential oil quality of Indonesian ceylon cinnamon at different age of harvest

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Abstract. Ceylon cinnamon is a world-famous cinnamon product produced mainly by Sri Lanka. In Indonesia, the distribution of Ceylon cinnamon is very limited. Fifteen Ceylon cinnamon promising lines in the Research Station at Laing, West Sumatera, have been chosen and observed for their yield and quality components. Plants that are usually harvested at the age of 4-6 years, can grow and develop into new branches, after being harvested. This study was aimed to determine the production capacity and quality of 15 accessions. The first harvest were performed at 6 years age, with bark production capacity 1,800 - 4,350 kg/tree, cinnamaldehyde content 42.23% - 61.24%. The following harvest had been carried out on new grown branches at 3 and 4 year ages, in which the production of bark, leaves, oil content and its quality, were varied for each accession. The yield components and essential oils quality of Ceylon cinnamon cultivated at a medium altitude were influenced by age of plant. Therefore, it is recommended that best harvesting would be 6 years after planting, and 4 years later on after the first pruning. Certain accession had optimum yield of bark and leaves, cinnamaldehyde content >60%, eugenol content >85%, and meets the international standard.

1. Introduction
Of the 54 species of cinnamon in the world, 12 are found in Indonesia [1]. Types of cinnamon that are widely cultivated are cassia vera or Padang cinnamon (Cinnamomum burmanii), Ceylon cinnamon or true cinnamon (C. verum, syn. C. zeylanicum) and Chinese cinnamon (C. cassia). Cinnamon is one of the most popular spice products in the world, especially countries in America and Europe. Cinnamon products traded on the world market are bark, as well as bark and leaves essential oils. The world's cinnamon producing countries are Sri Lanka, Seychelles, Madagascar, India, Indonesia, China, and Vietnam. There are four types of cinnamon products traded in the world, namely 1) Ceylon cinnamon, Cinnamomum verum, 2) cassia cinnamon, Cinnamomum cassia, 3) Saigon cinnamon, Cinnamomum loureiroi, and 4) Korintje cinnamon or cassiavera or Padang cassia, Cinnamomum burmanii. Ceylon Cinnamon are monopoly product of Sri Lanka. Indonesia is the main producer of cassia cinnamon known in the trading world as Korintje (Cinnamomum burmanii Bl.) or Padang cassia [2] . Cinnamon is traded as a spice, but it is also useful and can be used as medicine. One of the main functions of cinnamon powder as a medicine is for the treatment of diabetes with no evidence indicative of toxicity of C. zeylanicum [3]. High coumarin content in cassia cinnamon will damage liver tissue and even cause liver cancer. C. burmanii generally has a coumarin content of 0.4-0.8%, while Ceylon cinnamon <0.02%. C. zeylanicum also has anti-microbial, antiparasitic, anti-oxidant, free radical scavenging and wound healing properties. In addition, C. zeylanicum (CZ) may lower blood glucose, serum cholesterol...
and blood pressure, suggesting beneficial cardiovascular and metabolic effects [4]. The potential of the Indonesian Ceylon cinnamon market has the opportunity to fill the international market, because in addition to the low coumarin content, it also has an essential oil yield of >1%, cinnamaldehyde content > 6% and leaf eugenol > 85% [5] [6]. Further, the production of Ceylon Cinnamon in main producing country, Sri Lanka, has remained constant with the average annual productivity of ‘Ceylon Cinnamon’ at about 500 kg/ha, throughout the past thirteen years, and cultivated area has only shown a slight expansion over the past two decades [7]. This would become an opportunity for Indonesia to expand production not only for Cassia Cinnamon, but also Ceylon Cinnamon.

Ceylon cinnamon or known as true Cinnamon (Cinnamomum zeylanicum Blume) originates from Southwest India, Eastern Sri Lanka, and the Tenasserim Hills of Myanmar [8]. Ceylon cinnamon in Indonesia was probably brought by the Portuguese in 1770 [1]. This plant was first developed in West Java, then spread to West Sumatra in areas with elevations below 500 m above sea level. Ceylon cinnamon in Indonesian Spice and Medicinal Crops Research Institute was first planted in a forestry garden in Cikampek in 1908. In 1932, cinnamon from Cikampek was distributed to the Bogor Botanical Gardens and Cultuurtuin (the forerunner to the Research Institute for Spices and Medicinal Plants) in Cimanggu [9]. Ceylon cinnamon collection at Cimanggu Research Station, then propagated and replanted as a base collection of germplasm in the Cimanggu and Laing-Solok Research Station in 1984-1989. There are 35 accession numbers of the Ceylon cinnamon germplasm collection in the Laing Research Station, of which 15 accessions have been selected to be further characterized. This plant is usually harvested at 4-5 years old, and can grow and develop after pruning. In the first pruning of 6-year-old plants, bark yields ranged between 1,800 - 4,350 kg / tree with cinnamaldehyde content of bark ranging from 42.23% - 61.24% [5]. However, it is not yet known the characteristics of the production and the quality of the oil yield after pruning, as well as the optimum harvest age which can produce oil quality according to trade standards, after the first pruning. The research was aimed to evaluate the yield and bioactive compound of 15 accessions number of C. zeylanicum at different harvest ages.

2. Materials and methods

Material used were 15 accessions of C. zeylanicum, namely Czl 02, 03, 04, 08, 09, 11, 12, 15, 16, 17, 18, 22, 29, 30 and Czl35.

The study was conducted at the Laing Research Station, Solok, West Sumatera, from January 2007 to December 2018, at an altitude of 460 m above sea level with a soil pH of 5.5-6.0. Laing Research Station has climate types B (Schmidt & Ferguson) or C2 (Oldeman) with temperatures of 18.12-31.71 °C, rainfall of 1500-2000 mm.year-1 and humidity of 80-86% [10].

The environmental design used was a Randomized Block Design with 15 treatments (Ceylon cinnamon accessions) and 3 replications. The plot size used was 11 m x 8 m, with 12 plants per plot, plant spacing of 3 m x 3 m and spacing between plots 4 m, with a total population of 540 plants. The sample plants observed were 25% of the plot population.

The maintenance of plants carried out were weeding, loosening of the ring around the plant and trimming unneeded shoots. Application of organic fertilizer (manure) was done at the beginning of the year or the end of the rainy season. In the first and second year as much as 1 kg.tree-1, third year 2 kg.tree-1, fourth year 3 kg.tree-1, fifth year 4 kg.tree-1, and sixth year 5 kg.tree-1. Application of inorganic fertilizers (NPK 15; 15; 15) was done twice a year given at the end of the rainy season and at the end of the dry season at a dose per time in the first and second year of 100 g. trees-1, third year 200 g. trees-1, fourth and fifth year 200 g.trees-1 / year and sixth year 300 g.trees-1.

The parameters observed were production e.g. fresh weight of leaves, fresh weight of bark and dry weight of bark and quality (oil yield and component), at 6 years after planting, then at 3 and 4 years after first pruning. Production observations have been carried out by cutting down sample plants as high as 30 cm above ground level and then leaves and bark were harvested at the same day. Observation of quality characters include oil yield, cinnamaldehyde and eugenol content of the bark and leaves. Identification of the chemical components of stem bark and leaves oil was carried out using Gas
Chromatography-Mass Spectrophotometry (GCMS) conducted at PT. Mitra Ayu Cold Water Lubuk Minturun, Padang and DKI Jakarta Province Regional Health Laboratory (Lab. Dopping), Jakarta.

Data were analyzed according to the group of parameters observed. To observe the effect of harvest time and variety on the character of production a randomized block design in a 2 factor factorial pattern were used, with the first factor being harvest time and the second factor was variety/accession number. Quality of oils and bioactive compounds were displayed in the form of descriptive data.

3. Results and discussions

3.1. Cinnamon bark and leaves production

The interaction between accession and harvest time affected the three parameters observed (fresh bark weight, dry bark weight and leaf fresh weight). At 6-year-old stem harvests, Czl30 accessions showed the highest fresh bark weight, but were not significantly different from Czl08, Czl09, Czl16 and Czl17 accessions. At the age of 3 years after the first pruning, the varieties did not show any significant effect. Whereas in the 4 year harvest, Czl16 accessions were the highest, but not significantly different from Czl22 and Czl03 accessions (table 1). The data showed that, the average bark yield of 6 years harvested-old plant (4.98 kg per plant) slightly different to the one harvested at 4 years after first pruning (4.28 kg per plant). This suggesting that, Ceylon Cinnamon cultivated at medium altitude better to be re-pruning after 4 years from the first harvest, rather than at 3 years age.

Table 1. Interactions between accessions and harvest time on the fresh weight of Ceylon cinnamon bark (g) from Laing Research Station of Solok, West Sumatera

| Accessions | Harvest stem (6 years age) | Harvest branches (3 years after pruning) | Harvest branches (4 years after pruning) | Accession average |
|------------|-----------------------------|-------------------------------------------|------------------------------------------|-------------------|
| Czl02      | 4,566.67c                   | 3,105.00a                                 | 2,110.00e                               | 3,260.56c         |
| Czl03      | 3,516.67c                   | 1,802.67a                                 | 6,040.00b                               | 3,786.44bc        |
| Czl04      | 4,173.33c                   | 2,363.33a                                 | 4,800.00c                               | 3,778.89bc        |
| Czl08      | 7,266.67ab                  | 2,278.00a                                 | 2,240.00e                               | 3,928.22bc        |
| Czl09      | 6,000.00abc                 | 2,036.67a                                 | 3,230.00de                              | 3,755.56bc        |
| Czl11      | 4,933.33bc                  | 2,440.67a                                 | 3,980.00dcd                             | 3,784.67bc        |
| Czl12      | 3,853.33c                   | 2,782.67a                                 | 3,720.00dcd                             | 3,452.00bc        |
| Czl15      | 4,300.00c                   | 1,878.00b                                 | 5,760.00bc                              | 3,979.33bc        |
| Czl16      | 5,150.00abc                 | 3,008.33a                                 | 8,300.00b                               | 5,486.11a         |
| Czl17      | 5,300.00abc                 | 1,786.67a                                 | 3,440.00dcd                             | 3,508.89bc        |
| Czl18      | 4,266.67c                   | 1,306.00b                                 | 3,810.00bcde                            | 3,127.56c         |
| Czl22      | 4,475.00c                   | 1,780.00b                                 | 8,100.00a                               | 4,785.00bc        |
| Czl29      | 4,840.00bc                  | 2,212.33a                                 | 2,570.00de                              | 3,207.44bc        |
| Czl30      | 7,616.67c                   | 1,768.00b                                 | 2,800.00de                              | 4,061.56bc        |
| Czl35      | 4,476.67c                   | 2,763.33a                                 | 3,280.00de                              | 3,506.67bc        |
| HSD 5%     | 2,540.50                    | 2,540.50                                  | 1,466.76                                |
| Season average | 4,982.33c | 2,220.78c | 4,278.67b |
| CV         | 22.62                        |                                            |                                         |                   |

For the parameter of dry weight of the bark, it shows that the accession that gave the highest yield in 6-year-old stem harvest was Czl30. Harvest of branches at the age of 3 years after pruning the stems, shows that accession has no effect on the dry weight of the bark. Whereas at the 4-year old branch harvest, accessions of Czl22, Czl16 and Czl03 showed the highest dry-bark yields (Table 2).
Table 2. Interactions between accessions and harvest time on the dry weight of Ceylon Cinnamon bark (g) from Laing Research Station of Solok, West Sumatera

| Accessions number | Harvest stem (6 years age) | Harvest branches (3 years after pruning) | Harvest branches (4 years after pruning) | Accession average |
|-------------------|---------------------------|------------------------------------------|------------------------------------------|-------------------|
| Czl 02            | 2,366.67^{bde}           | 1,357.33^{a}                            | 1,130.00                                 | 1,618.00^{de}     |
| Czl 03            | 1,800.00^{a}             | 857.00^{a}                               | 3,300.00^{ab}                            | 1,985.67^{bcd}    |
| Czl 04            | 2,033.33^{cde}           | 1,131.67^{a}                            | 2,330.00^{bc}                            | 1,831.67^{cde}    |
| Czl 08            | 2,766.67^{bcde}          | 1,081.33^{a}                            | 1,230.00                                 | 1,692.67^{de}     |
| Czl 09            | 3,133.33^{b}             | 875.00^{a}                               | 1,700.00^{de}                            | 1,902.78^{bcd}    |
| Czl 11            | 2,300.00^{bcd}           | 1,140.00^{a}                            | 2,110.00^{de}                            | 1,850.00^{de}     |
| Czl 12            | 1,933.33^{de}            | 1,237.33^{a}                            | 1,900.00^{de}                            | 1,690.22^{de}     |
| Czl 15            | 2,300.00^{bcd}           | 906.00^{a}                               | 2,290.00^{cd}                            | 1,832.00^{de}     |
| Czl 16            | 2,816.67^{bcd}           | 1,366.00^{a}                            | 4,200.00^{a}                             | 2,794.22^{a}      |
| Czl 17            | 2,994.33^{bc}            | 840.00^{a}                               | 1,860.00^{de}                            | 1,898.11^{cde}    |
| Czl 18            | 2,050.00^{de}            | 648.67^{a}                               | 1,305.00^{de}                            | 1,334.56^{c}      |
| Czl 22            | 2,316.67^{bcd}           | 862.33^{a}                               | 4,280.00^{a}                             | 2,486.33^{ab}     |
| Czl 29            | 2,125.00^{de}            | 1,091.00^{a}                             | 1,330.00^{de}                            | 1,515.33^{de}     |
| Czl 30            | 4,350.00^{a}             | 1,093.33^{a}                             | 1,440.00^{de}                            | 2,294.44^{de}     |
| Czl 35            | 2,800.00^{bcd}           | 1,090.67^{a}                             | 1,820.00^{de}                            | 1,903.56^{de}     |
| HSD 5%            | 998.11                   | 998.11                                   | 998.11                                   | 576.26            |
| Season average    | 2,539.07^{a}             | 1,038.51^{c}                             | 2,148.33^{b}                             | 17.82             |

According to [7], in Sri Lanka the average annual productivity is around 500 kg of ‘Sri Lankan Cinnamon’ per hectare, and fluctuated yearly of about 3.5-5.5%. The average yield of dry bark amongst accession number tested in this experiment showed that at the first pruning (6 years old tree) resulted in 2,539 g per plant, meaning that there would be yielded of about 2,000 kg per hectare of dry bark (for about 800 trees of population per hectare).

Hence, the genetic potential of collected Indonesian Ceylon Cinnamon is promising to be expanded cultivation, even if there were harvested 4 years later on, after the first pruning, especially for Czl22, Czl16 and Czl03 (Table 2).

Similar to the character of fresh and dry weight of bark, for fresh leaves weight at the 3-year branches harvest, there was no interaction between harvest time and accessions used. At the 6-year stem harvest, the highest fresh leaf weight was performed by accession of Czl15, but not significantly different from Czl16. Whereas at the 4-year harvest, Czl15 accessions showed the highest yield of fresh leaves, although not significantly different from Czl17 (Table 3).

3.2. Cinnamon bark and leaves quality

The yield of leaf oil of 6 years age Ceylon cinnamon harvested at Laing were ranged from 0.50 to 1.45%, the highest was produced by accessions of Czl16 and Czl30. The yield of bark oil ranges from 0.26 to 0.58% [5]. The main components of cinnamon oil are cinnamaldehyde, eugenol, aceteugenol and other aldehydes. There was also methyl-n-amyl ketone which determine the specific flavor of cinnamon oil. GC-MS results showed various bioactive compound and yield for each part (bark or leaves oils) of each accession number evaluated, mostly for cinnamaldehyde and eugenol. Almost the same results were found for the three and four years age of branches harvested, both for leaves and bark. At three year of harvest there were about six chemical compounds detected in leaves oil, i.d., linalool, carophyllene, cinnamaldehyde, eugenol, benzyl benzoate, and acetyleneugenol. Eugenol was found to be dominant for both season of harvest, in which the four years harvested leaves showing higher eugenol content than that of the tree year harvest-leaves (Table 4). This results conform to other study which revealed that the major constituent of C. verum oils was eugenol [11] [12].
Table 3. Interactions between accessions and harvest time on the fresh weight of Ceylon cinnamon leaves (g) from Laing Research Station of Solok, West Sumatera

| Accessions number | Harvest stem (6 years age) | Harvest branches (3 years after pruning) | Harvest branches (4 years after pruning) | Accession average |
|-------------------|-----------------------------|------------------------------------------|------------------------------------------|-------------------|
| Czl 02            | 12,700.00<sup>def</sup>    | 10,415.00<sup>a</sup>                    | 6,050.00<sup>def</sup>                   | 9,721.67<sup>bde</sup> |
| Czl 03            | 7,633.33<sup>f</sup>       | 9,267.00<sup>a</sup>                     | 8,500.00<sup>edef</sup>                  | 8,466.78<sup>de</sup> |
| Czl 04            | 9,600.00<sup>def</sup>     | 9,986.67<sup>a</sup>                     | 6,080.00<sup>def</sup>                   | 8,555.56<sup>de</sup> |
| Czl 08            | 14,533.33<sup>abcd</sup>   | 7,155.33<sup>a</sup>                     | 4,180.00<sup>f</sup>                    | 8,622.89<sup>de</sup> |
| Czl 09            | 9,766.67<sup>def</sup>     | 7,886.67<sup>a</sup>                     | 4,535.00<sup>ef</sup>                   | 7,396.11<sup>c</sup> |
| Czl 11            | 12,200.00<sup>def</sup>    | 9,322.33<sup>a</sup>                     | 9,660.00<sup>bde</sup>                  | 10,394.11<sup>bcd</sup> |
| Czl 12            | 10,250.00<sup>def</sup>    | 9,317.33<sup>a</sup>                     | 5,690.00<sup>def</sup>                   | 8,419.11<sup>de</sup> |
| Czl 15            | 18,700.00<sup>a</sup>      | 8,263.33<sup>a</sup>                     | 17,400.00<sup>a</sup>                   | 14,787.78<sup>a</sup> |
| Czl 16            | 18,366.67<sup>ab</sup>     | 8,080.00<sup>a</sup>                     | 11,600.00<sup>bc</sup>                  | 12,682.22<sup>ab</sup> |
| Czl 17            | 11,726.67<sup>def</sup>    | 6,020.00<sup>a</sup>                     | 14,500.00<sup>ab</sup>                  | 10,748.89<sup>bcd</sup> |
| Czl 18            | 9,466.67<sup>def</sup>     | 5,742.33<sup>a</sup>                     | 5,600.00<sup>def</sup>                   | 6,936.33<sup>c</sup> |
| Czl 22            | 13,250.00<sup>bde</sup>    | 6,650.00<sup>a</sup>                     | 11,840.00<sup>bc</sup>                  | 10,580.00<sup>bcd</sup> |
| Czl 29            | 10,066.67<sup>def</sup>    | 7,648.67<sup>a</sup>                     | 6,950.00<sup>def</sup>                   | 8,221.78<sup>de</sup> |
| Czl 30            | 15,933.33<sup>bc</sup>     | 9,554.33<sup>a</sup>                     | 9,780.00<sup>bcd</sup>                  | 11,755.89<sup>bc</sup> |
| Czl 35            | 9,166.67<sup>ef</sup>      | 7,394.33<sup>a</sup>                     | 12,080.00<sup>bc</sup>                  | 9,547.00<sup>cde</sup> |
| HSD 5%            | 5,170.00                    | 5,170.00                                 | 5,170.00                                 | 2,984.90          |
| Season average    | 12,224.00<sup>a</sup>      | 8,180.22<sup>c</sup>                     | 8,963.00<sup>b</sup>                    | 18.00             |

For bark oil, there were ten bioactive compounds detected from three and four years harvested barks of Ceylon Cinnamon e.g. alpha-terpinene, beta-phellandrene, alpha-terpinolene, trans-Caryophyllene, Caryophyllene, Cinnamaldehyde, Cinnemyl acetate, 1-Phellandrene, trans-Cinnamyl acetate, Cinnamyl alcohol, with the most available and high content for Cinnamaldehyde (Table 5). There were no coumarins detected both from bark and leaves oils of all accession number evaluated. These results could be the prove to other study, especially the clinical trial for evaluating efficacy and safety of CZ, and confirmed that there was no significant side effects and toxicity of CZ, including hepatotoxicity and anti-coagulation properties [13]. Other study had mentioned a new look for the utilization of cinnamon oils, mainly cinnamaldehyde and eugenol, to be used as disinfectants for heritage textiles and their possibility to be an advantageous alternative for long term storage of textiles [14].

Continuously harvest and analysis of 6 years aged of bark, followed by cutting at 3 and 4 year aged of branches, revealed different content of essential oils which were varied between different harvest age and accessions tested. Harvest age of 4 years branches produced the highest levels of essential oils, followed by the age of 6 years and 3 years of branches. Czl08 and Czl30 accessions at 6 years of harvest showed high yields while at Czl16 they were produced at 4 years of harvest. The Cinemaldehyde content between the age of harvest and accession does not show much difference. Czl16 and Czl35 accessions harvested at 4 years of age give the highest yields.

Eugenol was highest in the 3-year harvest of the branch compared to the other two harvests. Accessions of Czl12, Czl17 and Czl35 which were harvested at 3 years saw the highest yields. This result showed essential oils and cinamaldehyde of cinnamon bark of Czl16 accessions harvested at the age of 4 years produce the highest levels (figure 1).

The essential oil content of leaves harvested from 3 year old branches is higher than the other two harvests. Czl16 and Czl30 accessions harvested at 3 years old showed the highest essential oil content. The Czl02 accession showed the highest cinamaldehyde content in both the 3-year and 4-year harvests. Meanwhile, eugenol levels between harvest time and accessions showed almost the same results (figure 1).
| Table 4. Bioactive compound of leaf harvested at three and four years after the first pruning of fifteen accession number of C. zeylanicum from Laining Research Station of Solok, West Sumatera |
|---------------------------------------------|
| **Bioactive** | **Accessions** | 3 years age | Chemical compound (%) | 4 years age | Chemical compound (%) |
| Czl 02 | Czl 03 | Czl 04 | Czl 08 | Czl 09 | Czl 11 | Czl 12 | Czl 15 | Czl 16 | Czl 17 | Czl 18 | Czl 22 | Czl 29 | Czl 30 | Czl 35 |
| Czl 02 | Czl 03 | Czl 04 | Czl 08 | Czl 09 | Czl 11 | Czl 12 | Czl 15 | Czl 16 | Czl 17 | Czl 18 | Czl 22 | Czl 29 | Czl 30 | Czl 35 |
| Linalool | 2.55 | 1.53 | 2.22 | 1.43 | 1.27 | 1.62 | 1.13 | 2.17 | 1.83 | 1.06 |
| Caryophyllene | 3.97 | 2.73 | 3.91 | 3.15 | 4.92 | 2.64 | 4.73 | 2.33 | 3.16 | 3.10 | 4.33 | 4.16 | 3.25 | 1.33 |
| Cinnamonaldehyde | 3.31 | 1.23 | 1.47 | 2.66 | 1.19 | 1.62 | 2.84 | 1.50 | 2.35 | 1.86 | 2.42 | 1.67 | 1.87 |
| Eugenol | 72.91 | 81.56 | 80.80 | 61.38 | 76.64 | 75.17 | 83.66 | 75.31 | 68.81 | 82.51 | 21.35 | 77.29 | 77.94 | 63.79 |
| Benzyl benzoate | 4.72 | 2.05 | 22.18 | 2.47 | 1.30 | 1.11 | 2.11 | 60.57 | 3.75 | 7.07 |
| Acetyl Eugenol | 2.96 | 4.33 | 9.46 | 8.11 | 4.93 | 4.05 | 22.35 | 20.58 | 3.78 | 1.74 | 3.54 | 2.69 | 24.54 |

| Eugenol | 57.53 | 41.12 | 93.63 | 92.14 | 88.42 | 90.04 | 93.40 | 91.76 | 95.31 | 80.97 | 94.75 | 94.15 | 95.39 | 93.88 | 92.12 |

| Table 5. Bioactive compound of bark harvested at three and four years after the first pruning of fifteen accession number of C. zeylanicum from Laining Research Station of Solok, West Sumatera |
|---------------------------------------------|
| **Bioactive** | **Accessions** | 3 years age | Chemical Compound (%) | 4 years age | Chemical Compound (%) |
| Czl 02 | Czl 03 | Czl 04 | Czl 08 | Czl 09 | Czl 11 | Czl 12 | Czl 15 | Czl 16 | Czl 17 | Czl 18 | Czl 22 | Czl 29 | Czl 30 | Czl 35 |
| Czl 02 | Czl 03 | Czl 04 | Czl 08 | Czl 09 | Czl 11 | Czl 12 | Czl 15 | Czl 16 | Czl 17 | Czl 18 | Czl 22 | Czl 29 | Czl 30 | Czl 35 |
| Alpha-Pinene | 1.97 | 4.95 | 5.73 | 10.3 | 9.08 | 1.27 | 1.47 | 1.05 | 5.11 | 5.36 | 1.14 | 3.95 | 2.00 | 3.79 |
| alpha-Terpinene | 1.39 | 1.36 | 1.42 | 3.30 | 2.46 | 2.42 | 1.59 | 1.96 | 1.93 | 1.96 | 1.93 | 2.15 | 1.82 |
| Linalool | 2.06 | 4.92 | 2.87 | 2.31 | 1.68 | 1.70 | 5.06 | 4.35 | 2.40 | 4.55 | 3.81 | 5.41 | 3.93 | 4.22 | 2.58 |
| Alpha-Terpinolene | 1.44 | 1.81 | 1.63 | 1.46 | 1.83 | 1.53 | 1.10 | 1.21 | 1.28 | 1.74 | 1.43 | 1.28 | 1.12 |
| Caryophyllene | 5.97 | 5.66 | 5.92 | 3.71 | 6.64 | 5.79 | 7.83 | 9.02 | 4.58 | 6.69 | 6.39 | 5.14 | 7.46 | 5.14 | 6.56 |
| Cinnamaldehyde | 40.4 | 42.05 | 50.27 | 49.97 | 39.79 | 42.39 | 42.24 | 41.38 | 49.59 | 38.58 | 52.59 | 53.59 | 52.45 | 48.29 | 53.46 |
| trans-Cinnamyl acetate | 15.9 | 18.55 | 14.82 | 12.07 | 16.94 | 16.54 | 15.88 | 16.12 | 17.31 | 18.60 | 15.84 | 14.11 | 13.61 | 13.01 | 19.15 |
| Cinnamyl alcohol | 1.79 | 1.99 | 1.07 | 1.09 | 1.36 | 1.21 | 1.94 | 1.48 | 1.32 | 1.24 | 1.46 | 1.29 | 1.09 |
| alpha-Terpinene | 1.73 | 1.75 | 1.59 | 2.3 | 2.14 | 1.38 | 1.69 | 1.5 |
| beta-Pinene | 4.73 | 1.30 | 5.05 | 1.88 | 2.47 | 4.38 | 6.6 | 3.98 | 2.32 | 4.42 | 2.84 | 4.71 |
| Alpha-Terpinolene | 2.52 | 1.52 | 1.03 | 1.24 | 2.48 | 3.97 | 1.33 | 1.97 | 1.46 | 3.2 | 3.95 | 1.41 |
| trans-Caryophyllene | 2.43 | 4.37 | 3.24 | 8.1 | 4.57 | 1.76 | 1.23 | 8.53 | 5.01 | 1.33 |
| Caryophyllene | 3.52 | 3.90 | 3.8 | 2.69 | 6.97 | 1.04 |
| Cinnamaldehyde | 35.91 | 62.89 | 55.1 | 60.27 | 66.5 | 43.28 | 49.05 | 47.13 | 67.7 | 38.5 | 57.35 | 51.86 | 58.3 | 56.08 | 63.35 |
| Cinnamyl acetate | 6.13 | 7.42 | 8.34 | 10.41 | 2.65 | 15.92 | 10.55 | 7.92 | 6.23 | 7.37 | 15.69 | 10.92 |
| Eugenol | 3.05 | 3.76 | 11.66 | 2.66 | 5.37 | 15.97 | 3.38 | 1.36 | 16.1 | 3.53 | 4.81 | 6.54 | 3.26 | 7.15 |
Yield and quality of essential oils from both of bark and leave for each accessions number at different harvest were as figure 1.

![Figure 1](image-url)

**Figure 1.** Yield and quality of essential oils for each accessions number at different harvest. (a) bark essential oils (b) bark cinnamaldehyde (c) bark eugenol (d) leave essential oils (f) leave cinnamaldehyde (g) leave eugenol

From the above-mentioned results, it could be recommended that harvesting of Ceylon Cinnamon cultivated at a medium altitude, would be 6 years after planting, and 4 years later on after the first pruning. At that stage, optimum yield of bark would be obtained as well as cinnamaldehyde content, the leaves yield and its eugenol content. In contrast to *C. burmanii*, which shows a tendency to increase quality in line with increasing plant age, in Ceylon cinnamon, age becomes a limiting factor for the quality and bioactive content. The results of the analysis of the bark and leaf quality of plants aged 34, 67, and 87 years from others plantation showed a significant decrease in Cinnamaldehyde content of the
bark, even in plants aged 87 years, cinnamaldehyde was very low (5.42%) and a high Camphor content was detected, 50.13% (table 6). Champor is usually obtained from *Cinnamomum champora* bark or camphor tree, and its used in therapeutics for skin care. According to [15], champor in CZ is usually found in the root.

**Table 6.** Quality of Ceylon Cinnamon bark and leaves at ages 34, 67 and 87 years from Cimanggu and Cikampek Research Station

| Accession number | Origin  | Age (year) | Essential oils content (%) | Eugenol (%) | Cinnamaldehyde (%) |
|------------------|---------|------------|---------------------------|-------------|--------------------|
|                  |         | Bark       | Leaves                    | Bark        | Leaves             | Bark              |
| CKP85            | Cikampek| 34         | 0.51                      | 0.84        | 13.34              | 85.36             | 19.59             |
| CIM32*           | Cimanggu| 87         | 1.12                      | 1.12        | 5.45               | 93.09             | 5.42*             |
| CIM52-1          | Cimanggu| 67         | -                         | 1.17        | -                  | 89.53             | -                 |
| CIM52-2          | Cimanggu| 67         | -                         | 0.92        | -                  | 84.60             | -                 |
| CIM52-3          | Cimanggu| 67         | -                         | 1.20        | -                  | 89.36             | -                 |
| CIM52-4          | Cimanggu| 67         | -                         | 0.84        | -                  | 90.03             | -                 |
| CIM52-5          | Cimanggu| 67         | 0.63                      | 1.00        | 15.38              | 64.80             | 43.44             |
| CIM52-6          | Cimanggu| 67         | -                         | 1.00        | -                  | 48.89             | -                 |

Note: *CIM32, bark contains Camphor 50.13%; - Not analyzed.*

4. Conclusions

Yield components, quality and bioactive content of Ceylon Cinnamon were influenced by age. The optimum yield and quality of Ceylon Cinnamon cultivated at medium altitude, were performed at 6 years after planting and the second harvest would be at 4 years after the first pruning. There was no coumarin detected from bark and leaves oils of Ceylon Cinnamon of 15 accession number evaluated.

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