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RESEARCH ARTICLE

Vegetative and reproductive phenology of *Cinnamomum verum* J. Presl grown in intermediate climatic zone of Sri Lanka

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Abstract: Efficient harvesting of cinnamon while maximizing the yield is highly dependent on its phenology. Many important studies on Ceylon cinnamon have been undertaken, though in-depth studies on vegetative and reproductive phenology of *Cinnamomum verum* are limited. Therefore, this study investigated the vegetative and reproductive phenology of *C. verum*, giving particular emphasis on the major phenological phases such as leaf flushing, flowering, and fruiting. The investigation was carried out during January 2018 to March-2019 to cover a complete annual phenological cycle at the Thihagoda site, in the intermediate climatic zone of Sri Lanka. The results indicate that the leaf emergence of *C. verum* in Sri Lanka takes place in flushes which appeared to be controlled by two factors, the seasonality and the rainfall after a dry period. The seasonal flushing took place in the four months period from February to May. The leaf longevity of *C. verum* in Sri Lanka is longer than 15 months. The leaf fall was not continuous and limited to a five -month period from March to July with a peak in March. The flowering in *C. verum* took place during October and November, however only 18.6 ± 5.6% of flower buds matured to flowers. Moreover, 94.1 ± 8.5% of flowers developed into young fruits. The timing of these phenological traits is important to manage the cinnamon productivity as it is recognized that the peeling ability of *C. verum* depends on the cambial activity which is controlled by source-sink relationships in assimilate partitioning in *C. verum*.

Keywords: Annual cycle, *Cinnamomum verum*, peelability, phenology.

INTRODUCTION

Cinnamon or true cinnamon, *i.e., Cinnamomum verum* is one of the important economic crops in Sri Lanka. It provides export earnings of nearly 31,000 million rupees annually (Department of Export Agriculture, 2018). Accordingly, cinnamon is at the top among the minor export crops of Sri Lanka, in terms of export earnings. Among the cinnamon cultivating countries, Sri Lanka is the world's largest true cinnamon producer and it is mainly used as a spice or food additive (Pushpitha, 2006). In addition to the condiment and flavoring value, cinnamon is being used as a herbal medicine due to its antioxidant, anti-inflammatory, and anti-diabetic properties (Wiart, 2002; Rao & Gan, 2014). Moreover it provides various chemicals such as cinnamaldehydes, alkaloids, eugenol, proanthocyanidin, flavonoid, and terpenoid for pharmaceutical and perfume industries (Wiart, 2002). *C. verum* belongs to family Lauraceae and the genus *Cinnamomum* consists of about 250 species of evergreen trees and shrubs, distributed in Asia and Australia (Rani *et al*., 2017). There are eight *Cinnamomum* species recorded in Sri Lanka (*i.e.*, *C. dubium* Nees, *C. citriodorum* Thw., *C. capparu coronde* Blume, *C. litseaefolium* Thw., *C. ovalifolium* Weight, *C. rivulorum* Kostermans, *C. sinharajaense* Kostermans and *C. verum* J. Presl) and all of them

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grow naturally in the wild. However, *C. verum* is the only species domesticated and cultivated commercially in Sri Lanka. Cinnamon produced from *C. verum* is exported to the world market as true cinnamon (or Ceylon cinnamon). *C. verum* is cultivated in about 30,000 ha in Sri Lanka and it is mainly distributed in part of the wet zone including Galle, Kalutara, Kandy, Matale, Rathnapura, Nuwara Eliya, Kegalle and in the intermediate zone including Matara, Badulla, and Monaragala (Figure 1). There is another cinnamon species, *i.e*., *Cinnamomum cassia* Blume (Cassia cinnamon), grown commercially in China, Indonesia, and Vietnam (Thomas & Kuruvilla, 2012); they produce more than 82.5% of the world supply of cinnamon (Ravindran *et al*., 2004). However, Ceylon cinnamon is considered superior to Cassia cinnamon and the superiority is mainly due to the better taste and lower content of the toxic compound, Coumarin (Ravindran *et al*., 2004). Mainly, five important items are produced from the cinnamon plant namely, quills, featherings, chips, bark oil and leaf oil in Sri Lanka. Quills are the major product of export, which accounts for 90% among the other cinnamon products (Pushpitha, 2006). As the leading producer, Sri Lanka provides around 90% of the true cinnamon supply in the world, while the Seychelles, India and Madagascar produce the rest (Ravindran *et al*., 2004).

Some studies on *C. verum* covering taxonomic features (Abeysinghe & Scharaschkin, 2019), genetic relationship among the species and varieties (Abeysinghe *et al*., 2014), eco-physiological aspects and chemical composition with special attention to essential oils (Wijesinghe *et al*., 2004; Saumyasiri *et al*., 2006), soil fertility and plant nutrition management (Samaraweera *et al*., 2013), insect pest management and plant protection (Jayasinghe *et al*., 2006), agronomy (Abeykoon, 1998), crop improvement and varietal development (Wijesinghe & Pathirana, 1998), cinnamon characterization, phylogenetics and special variations in the quality of products (Wijesinghe *et al*., 2008) etc. have been carried out in Sri Lanka during the past. However, there are no publications on the phenology of *C. verum* in Sri Lanka even though knowledge on vegetative and reproductive phenology is important in managing the productivity of cinnamon cultivations. Particularly, cinnamon cultivators in Sri Lanka face a problem in harvesting their crops (or getting the bark extracted) as the peelability (*i.e*., easiness of removing the bark from the stem) varies from time to time. This variation interrupts harvesting of *C. verum* throughout the year and the peelability variation seems to be governed by many factors such as edaphic and/or climatic factors. Publications on reproductive or vegetative phenology of cinnamon in relation to peelability variations are scanty. Thus, it is important to conduct phenological research for cinnamon to boost the cinnamon industry in Sri Lanka.

Phenology is the timing of plant and animal life cycle activities parallel to the seasonality (Leith, 1974). Phenological studies involve observation, recording, and interpretation of the timing of life history events of plants (Fenner, 1998) and such studies are important to understand the species interactions and community functions. Furthermore, phenological models can be used to assess the impact of climate change on the functioning and productivity of different ecosystems (Kramer *et al.,* 2000). Phenological events of the plants which are, regulated both by biotic and abiotic factors are important to avoid competition for pollination by either attracting or dispersing pollinators.

Understanding of such behavior of the communities is useful in developing a proper management strategy. Information on phenology is essentially useful in predicting the interactions of plants and animals to the changing environment (Bhat *et al*., 2001). Furthermore plant phenology plays a major role in the pest-plant relationship. Host plant selection and host shifts of certain plants depend on the plant phenology (How *et al*., 1993). For the timing of management practices in certain crops (Ansquer *et al*., 2009) and to assess the effect of climate change on plants (Post & Stenseth, 1999), the study of phenology is of great importance. Also phenological studies allow efficient crop management and harvesting, thereby maximizing the yield.

Therefore, this study aimed to explore the vegetative and reproductive phenological variations of *C. verum* in Sri Lanka. Accordingly, the following research questions were addressed: a) What are the patterns/trends of vegetative and reproductive phenology of *C. verum*? b) What factor/s may govern the phenology of *C. verum*?

METHODOLOGY

Study area

Out of the total extent of *Cinnamomum verum* planted in Sri Lanka, only 10 % is distributed in the dry zone. Even though the percentage coverage in the wet zone (62 %) is the highest (Punyawardene, 2008), the distinction between dry and wet seasons is not much pronounced in the wet zone as the rainfall is distributed throughout the year. On the other hand, some phenological variations should be measured at very short intervals, with all the measurements taken by the same person to reduce the personal errors. Thus, the intermediate zone was selected to conduct phenological observations and cinnamon plantations in the premises of the Cinnamon Research Institute at Thihagoda (6^0 03'N, 80^0 56'E) were selected for the study (Figure 1). Meteorological data (rainfall and air temperature) from Matara were obtained as it is the meteorological station closest to the study site. The total annual rainfall of Thihagoda area was 1239.9 mm and the mean annual temperature was 26.9 ± 0.35 ^{0}C during the study period. The studies were carried out from January 2018 to March 2019.

Study design

The total coverage of the cinnamon plantation under the Cinnamon Research Institute is about 16 ha and the plantation has been established covering a set of small hillocks and flat lands (between hillocks). The elevation of the area is 22.3 m.a.s.l. Therefore, plants for the phenological study were selected to represent the three geomorphological settings; valleys between hillocks, slopes of hillocks, and tops of hillocks. Accordingly, altogether 12 plants, each with a diameter larger than 2.5 cm, were selected randomly to include four plants for each of the geomorphological settings. Cinnamon

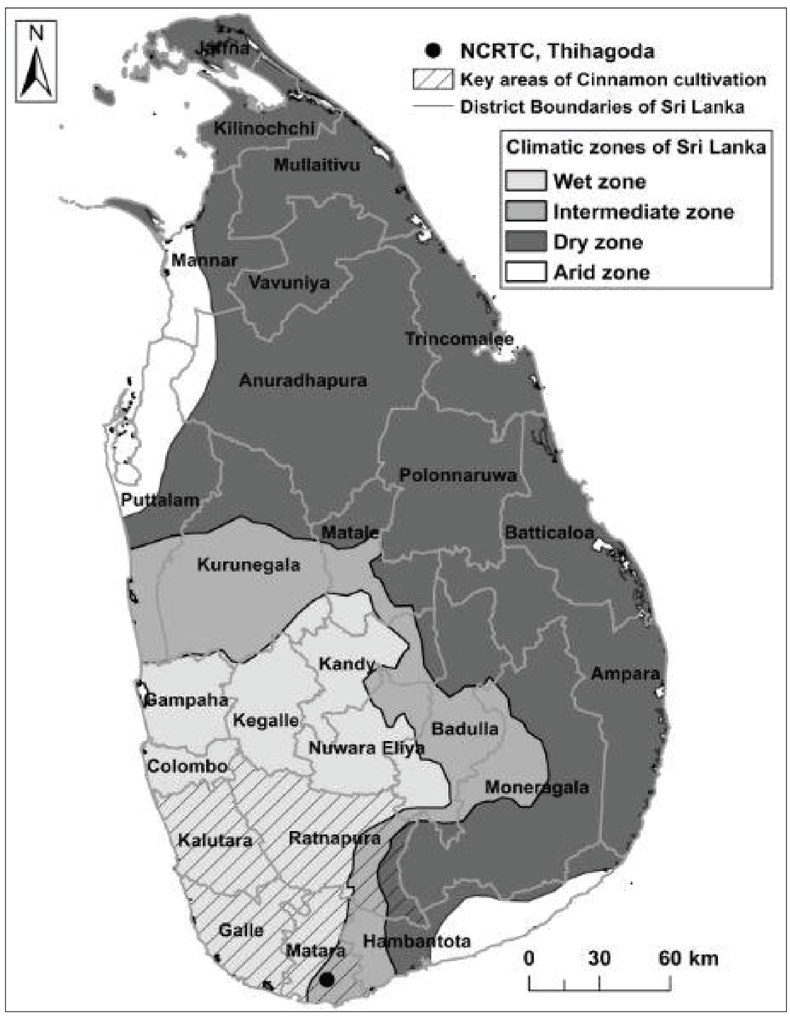

Figure 1: The map of Sri Lanka showing the major climatic zones, the cinnamon cultivated areas of the country and the study site at the premises of Cinnamon Research Institute (Source: Punyawardene, 2008)

plants with a Diameter ≥ 2.5 cm were used for the phenological measurement as the individuals of the same size are selected for harvesting in the cinnamon industry.

Phenological observations

The phenological observations were taken on pheno-phases such as, (1) leaf emergence/initiation and maturation, (2) initiation of floral buds and flowering, (3) fruiting, and (4) leaf and fruit shedding, for a period of 15 months starting from January of 2018. Three branches at three different heights of each plant (in total, 36 branches) in all locations were marked and used for the phenological observations.

These selected shoots were tagged by using numbered plastic strips which were looped around the stem of 'study branches' keeping five leaves and a bud above the tag (hereafter the term 'study branch' is used in this research to designate such twigs with five leaves, and their progressive growth including new leaves and new branches produced).

Vegetative phenology

Those study branches were used to monitor the emergence of new leaves, their growth and leaf fall. Five leaves above the tag in the study branches were numbered consecutively on the adaxial surface with a xylene free permanent marker. Those study branches were checked once a week for the emergence of new leaves. Any young leaves above the numbered leaves on these shoots were treated as newly emerged leaves and were labeled in the same way giving consecutive numbers. The total number of leaves in each shoot was counted at each visit over the monitoring period. The emergence of any lateral shoot, producing new branches above the tag was considered together in counting of the leaves in each branch. Loss of a senescent leaf from the selected branches was considered as a leaf fall.

The growth rates of leaves were measured at three different times/seasons, *i.e.*, budding period, developing stage, and mature stage, during the study period by starting from a newly emerged leaf bud. The maximum length of the leaf blade, of the selected leaves were recorded from the day of the first observation until its fall. Growth measurements were taken daily at the young stage, but the measuring frequency gradually decreased up to once a week with the maturity of the leaves.

Reproductive phenology

Emergence of new flower buds, and their development until blooming, fruit set, and their development until the fruit drop were studied. Newly emerged flower buds in study branches were monitored during the study period continuously for their progress. The increase in the size of flower buds were measured once a week or more frequently until the flowers were open. The same shoots used to monitor the progress of flower buds were carefully observed from the open flower to the fruit set ,and then until the ripened fruits were shed. The sizes of the fruits were measured once a week or more frequently as necessary, in order to record the exact timing of fruit drop. The total number of flower buds, flowers, and fruits on the study branches were counted once a week. The above measurements were started initially with a higher number of replicates, as a precautionary measure to compensate for any damage caused by the pests, including monkeys. Replicates damaged by pests were discarded and a minimum of three undamaged replicates were used in the data analyses.

Statistical analysis

Leaf length and fruit length were considered continuous variables while number of leaves per branch, number of flower buds per branch, number of flowers per branch,

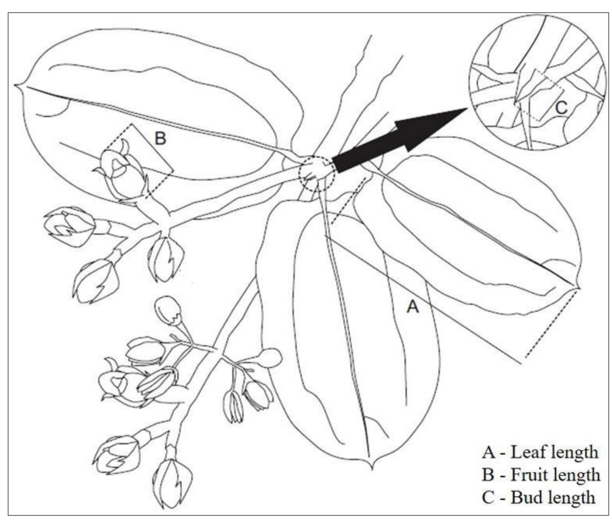

Figure 2: The measurements of leaf length, fruit length and bud length measured in the phenological study.

and number of fruits per branch were treated as count data. Descriptive analysis was performed to calculate the mean, variance and standard error. Prior to all the analyses, Shapiro-Wilk's and Levene's tests were used to examine the data for normality and homogeneity of variance, respectively. The Pearson correlation test was performed to check the correlation between rainfall and the variable, number of leaves (leaf- emergence). Generalized Linear Model (GLM) with Poisson distribution was carried out to check the significance difference of the number of flower buds and number of fruits in the dry season and rainy season. One-way ANOVA was performed to check the significance of leaf length and fruit length in the aforementioned two seasons. All the analyses were conducted by using the R-3.2.2 statistical programme.

RESULTS AND DISCUSSION

Climatic conditions of the study site

The mean monthly rainfall of the study area was 94.04 ± 20.69 mm and the rainfall in the months of February, March, April, July, August, September, November, and December were lower than that of the mean value, while it was higher than the monthly mean rainfall in the other months, *i.e.*, January, May, June, and October (Figure 3).

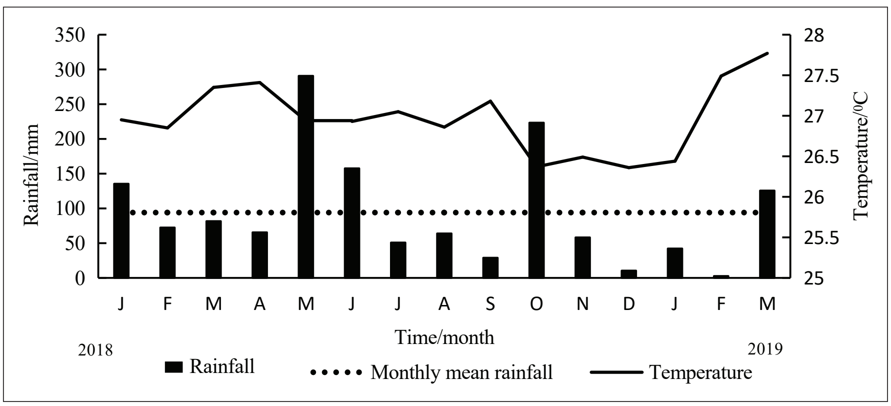

Figure 3: Variation of the mean monthly rainfall and temperature of the study area (2018-2019), 12.5 km from the study site (Source: Meteorological Station, Matara)

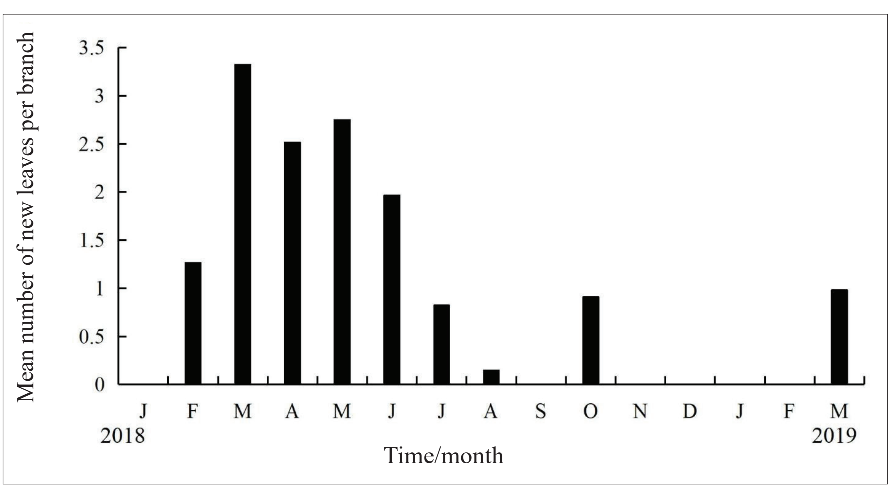

Figure 4: Variations in the mean number of new leaves per branch of *Cinnamomum verum* over 15 month-period (January 2018 to March 2019)

Vegetative phenology

Emergence of new leaves and leaf growth

The leaf emergence of *C. verum* showed a multimodal pattern in which leaf emergence was apparent during the months of February to June (Figure 4). However, the leaf emergence scenario displayed mixed- multimodal pattern. The highest and second highest values of leaf emergence were observed in March and May of 2018, respectively. Hence the four-month period (February to May) can be considered as the period of leaf flushing. Considerably higher leaf emergences were observed in February, July, and October 2018 and March 2019. The leaf emergence in all the other months was zero or negligible.

A leaf started from a leaf bud/primordium and it was observed that a leaf primordium took mean duration of 29.0 ± 8.5 days to become an opened leaf. Leaves were opened and then grew slowly increasing their size, reaching to their maximum mean length of 63.7 ± 4.0 mm, in a mean duration of 57 ± 16 days. Afterwards, the leaf remained a long period without further increase in size. None of the leaves that emerged at the beginning of the study showed any sign of senescence, indicating that the life span of a leaf of *C. verum* is longer than 15 months (Figure 5).

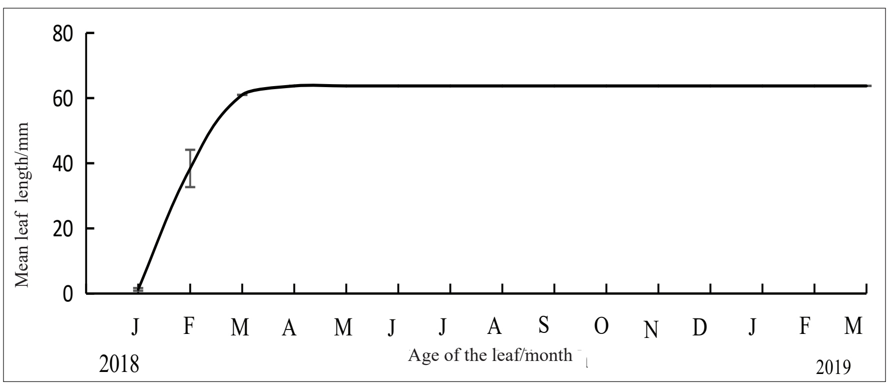

Figure 5: The leaf development of *Cinnamomum verum* in mean leaf length (mm) over 15 months study period (January 2018 to March 2019). Error bars represent standard error of the mean.

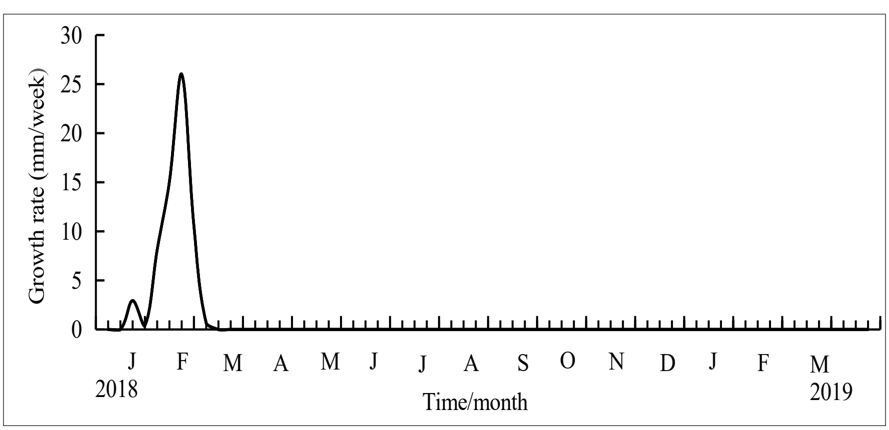

Figure 6: Mean growth rate of the leaf of *Cinnamomum verum* during the study period

The emergence of new leaves of *C. verum* is not all-year round and a sporadic nature in leafing was observed, in addition to the peak in the four-month period from March to June. The above sporadic increases of the leaf emergence were compatible with the high rainfall, but not fully compatible with the peak of leafing from March to June (Figure 3). However, based on the data collected in this study, the mean rate of leaf emergence in *C. verum* was 1.14 ± 0.29 new leaves/branch/month. According to the Pearson correlation, rainfall showed a significant correlation with leaf emergence r = 0.656; df = 13, p = 0.00867) and it explained 65 % of the total correlation.

The mean growth rate of leaves of *C. verum* had two peaks. The first small peak was observed during the first 2 weeks due to the growth of leaf primordia, and the second large peak was observed during the next 5 weeks period due to the growth of the opened leaf (Figure 6).

In an evergreen perennial plant, the emergence of leaves can take place either continuously throughout the year (Munne-Bosch, 2007) or as flushes, *i.e.*, a higher number of leaves produced within few days or few weeks and no leaf emergence during the next few months. The leaf emergence of *C. verum* in Sri Lanka takes place, not on a regular or continuous basis, but in flushes, as evidenced in this study.

Young leaves are reddish in color at the leaf initiation and then turn to dark green at the end, being greenish yellow at the transition of young leaves to mature leaves. The time period between two flushes and the intensity of the flush appeared to be controlled by two factors: the inherent seasonality and the rainfall after a dry period. In this study, it was revealed that the emergence of leaves started in February, reached to a peak in March and remained at the peak until May and then gradually decreased during the next two months. In addition to this main leaf flush during a six months period, there were two isolated leafing events in October and March of the following year and these two events overlapped with high rainfall.

However, rainfall is very low during the first half of the main leaf flush, *i.e.*, during the three months period from February to April, indicating that the leaf flush during this period is not triggered by the rainfall, but some other factor(s). Therefore, we suggest that this scenario could be linked with an inherent factor such as evolutionary adaptation to the 'spring,' that is, from February to April in the northern hemisphere. However, further studies are required to confirm it. The two isolated leaf flushes in October 2018 and March 2019, as well as the second half of the main leaf flush from May to June, 2018, overlapped with rainfall after dry spells. Hence, it can be surmised that the high rainfall after a dry spell also trigger the leaf emergence in *C. verum* in Sri Lanka. Singh and Kushwaha (2005b) have also reported that when there is a severe drought, the plant tends to survive with a long growth constraining dry period, and produces a flush of new leaves in the following rainy season. The availability of enough water for the favorable growth of leaves ensures the emergence of a new flush in the rainy season (Monasterio & Sarmiento, 1976; Falkenmark *et al*., 1989).

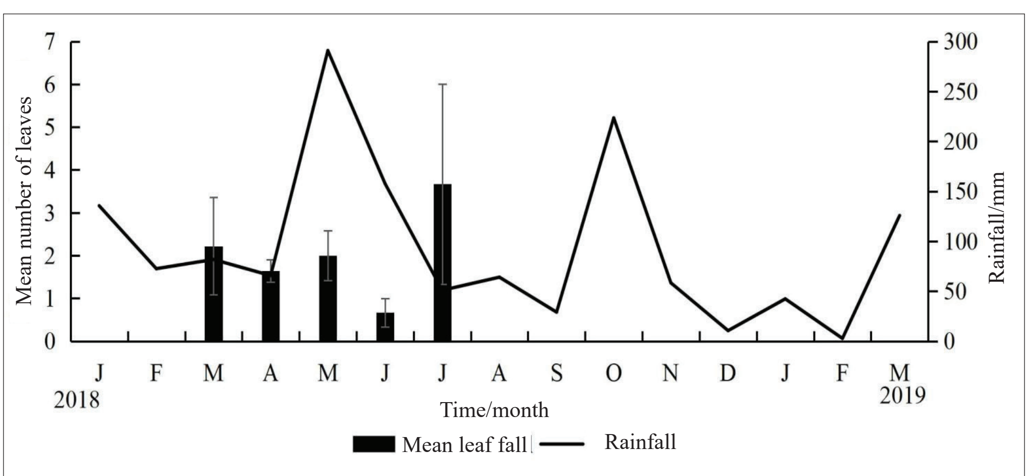

Figure 7: Variations in the mean number of leaf fall of *Cinnamomum verum* over a 15 month-period (January 2018 to March 2019). Error bars represent standard error of the mean.

During the study period, few leaves were fallen in the 5-month period from March to July and at least sporadic leaf fall was not observed during the rest of the 10-month period (Figure 7). The monthly average leaf fall was 0.85 ± 0.71 leaves/branch/month.

None of the newly emerged leaves during the study period of 15 months were fallen and at least had not reached senescence, indicating that the leaf longevity of *C. verum* in Sri Lanka is longer than 15 months. Further studies are required to find out the exact leaf longevity of *C. verum* in Sri Lanka. A longer life span of leaves in any plant further indicates a few other features; the number of leaves produced by such a plant within a specified period is comparatively less and their photosynthetic rate is also low, but it does not decrease rapidly through time (Kikuzawa, 1995). However, the life span of leaves of *C. verum*, may not be very long, because, out of the five leaves which were already there in 'study branches' when the study was commenced, 2.04 ± 1.08 leaves dropped during the study period. Moreover the leaf fall of *C. verum* was not continuous and limited to five-month period from March to July. This indicates that the leaf fall has one major peak of March to July.

Reproductive phenology

Flowering

Floral bud initiation in *C. verum* plants started in the month of September and showed a peak, in October (Figure 8). More precisely it was a single peak and the occurrence of flower buds was limited to a five weeks period, from the 3rd week of September to the 3rd week of October. Flower buds appeared in a panicle and the mean length of a panicle was 167.3 ± 9.5 mm. The mean number of flower buds per panicle was 33.5 ± 10.5. Flower production commenced in early October and showed a peak at the 3rd week of October, in particular, a single peak at the 41st week. A flower bud took an average of 14 ± 4 days to become an open flower; however only 18.6 ± 5.6 % of the flower buds became open flowers and rest of the flower buds dropped. The flower production of *C. verum* was significantly lower than the bud production ($P < 0.05$). The peak of open flowers was observed in the 3rd week of October showing two week difference between the peaks of flower buds and open flowers. A flower of *C. verum* remained open approximately for 12 hours in the morning.

In this study the flowering in *C. verum* took place during October and November and it is compatible with other reports in Sri Lanka (Ravindran *et al*., 2004; Azad *et al*., 2018). Even though some studies report off season flowering in March and April (Azad *et al*., 2018), in this study we observed only one flowering event for the whole study period. The time period from the initiation of the flower bud to the open flower is about 14 ± 4 days. However, flowers of all the cinnamon trees do not bloom at the same time. Azad *et al*., (2018) reported that cinnamon flowers exhibit protogynous dichogamy with two flower types as "Type A" and "Type B" in separate individual plants of which, flowerings during morning and flowerings during evening, respectively creating a temporal barrier for self-pollination. However, most of the flower buds produced within this period has dropped, leaving a smaller percentage of pollinated flowers to be converted to young fruits. This study indicates that only about 18.6 ± 5.6% of flower buds become flowers. The rest of the flower buds dropped. Such a high percentage of dropping flower buds could be due to higher rainfall in the same season. There are many reports to confirm that highe rainfall during flowering season could reduce the number of fruits produced (Davies, 1976). However, almost all the remaining flowers were able to produce young fruits, indicating that pollination has not been a limiting factor. It is reported that cinnamon flowers get pollinated mainly by wind (Ravindran *et al*., 2004). In this study, only about 25 ± 3 % of the young fruits survived to become mature fruits and it took about six months for a young fruit to mature. This observation is compatible with the study carried out in Sri Lanka (Amador, 2019); GLM results showed that the number of flower buds (initiation of flowering) and the number of fruits (fruit production) were significantly higher in the rainy season as compared to the dry season [$p = 0.0012$; null-deviance: 15.77 ($df = 18$); $p = 0.0341$; null-deviance: 27.21 ($df = 16$) respectively]

Fruiting

Smaller fruits of *C. verum* were first observed during mid-October (Figure 9). Fruit production peaked at the end of October, showing a unimodal response (Figure 8). It was observed that only 94.1 ± 8.5 % of flowers developed into young fruits. The mean number of fruits per branch was 7.5 ± 3.6. However, few or no new fruits were produced after the month of October. In other words, the number of fruits did not show any further increase after 2nd week from the start of the fruit initiation. All fruitlets did not develop to a mature fruit as a considerable number of fruitlets dropped, and out of the young fruits, only 25 ± 3 % got developed into mature fruits. Therefore, the number of fruits was reduced during the 20 week period from January to March, 2019. The maximum fruit length recorded was 17.0 ± 0.3 mm and it was observed in February, 2019. One-way ANOVA results showed that leaf length and fruit length have significantly increased during the rainy season ($F = 32.2_{1,9}$; p = 0.0025; $F = 28.4_{1,8}$; p = 0.0267). When the timing of the above flowering, fruiting, and fruit shed are considered, the six month period from September to March can be considered as the reproductive phase of *C. verum* growing in the study area.

The phenological knowledge of a crop plant or 'the knowledge in the timing of recurring vegetative and reproductive events, their interactions to biotic and abiotic forces, and their interrelation of those aspects with other species' (Leith, 1974) can provide important information useful in development of that particular crop. Even though *C. verum* is the most important minor export crop in Sri Lanka, to the best of our knowledge, there is no phenological study conducted on *C. verum* in Sri Lanka. However, there are a few studies which

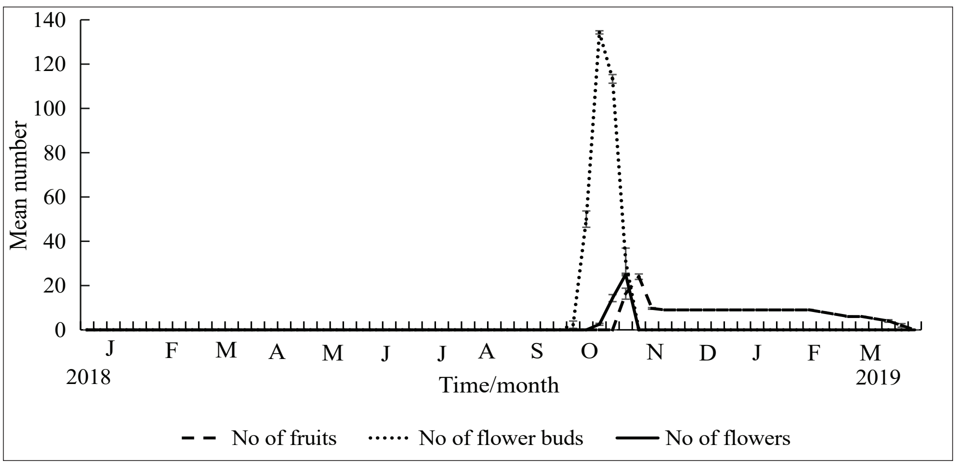

Figure 8: Variations in the mean number of flower buds, mean number of flowers and mean number of fruits of *Cinnamomum verum* per study branch during the 15 month study period (January 2018 to March 2019). Error bars represent standard error of the mean.

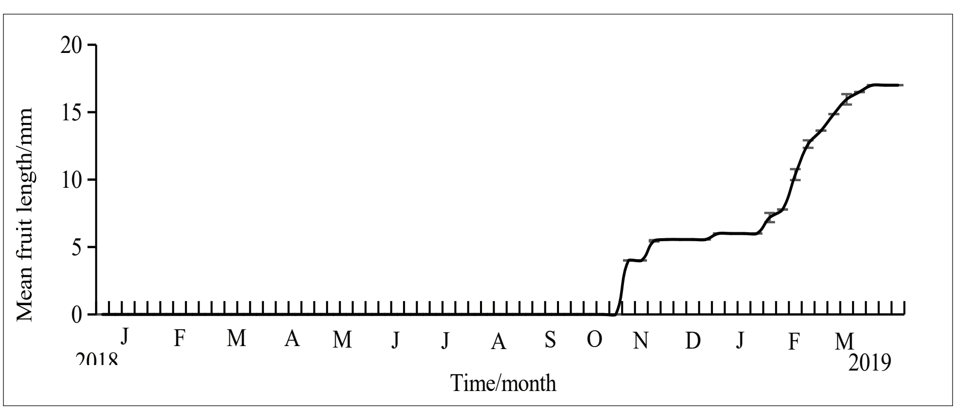

Figure 9: Variations in the mean fruit length (mm) of *Cinnamomum verum* per study branch during the 15 month study period (January 2018 to March 2019). Error bars represent standard error of the mean

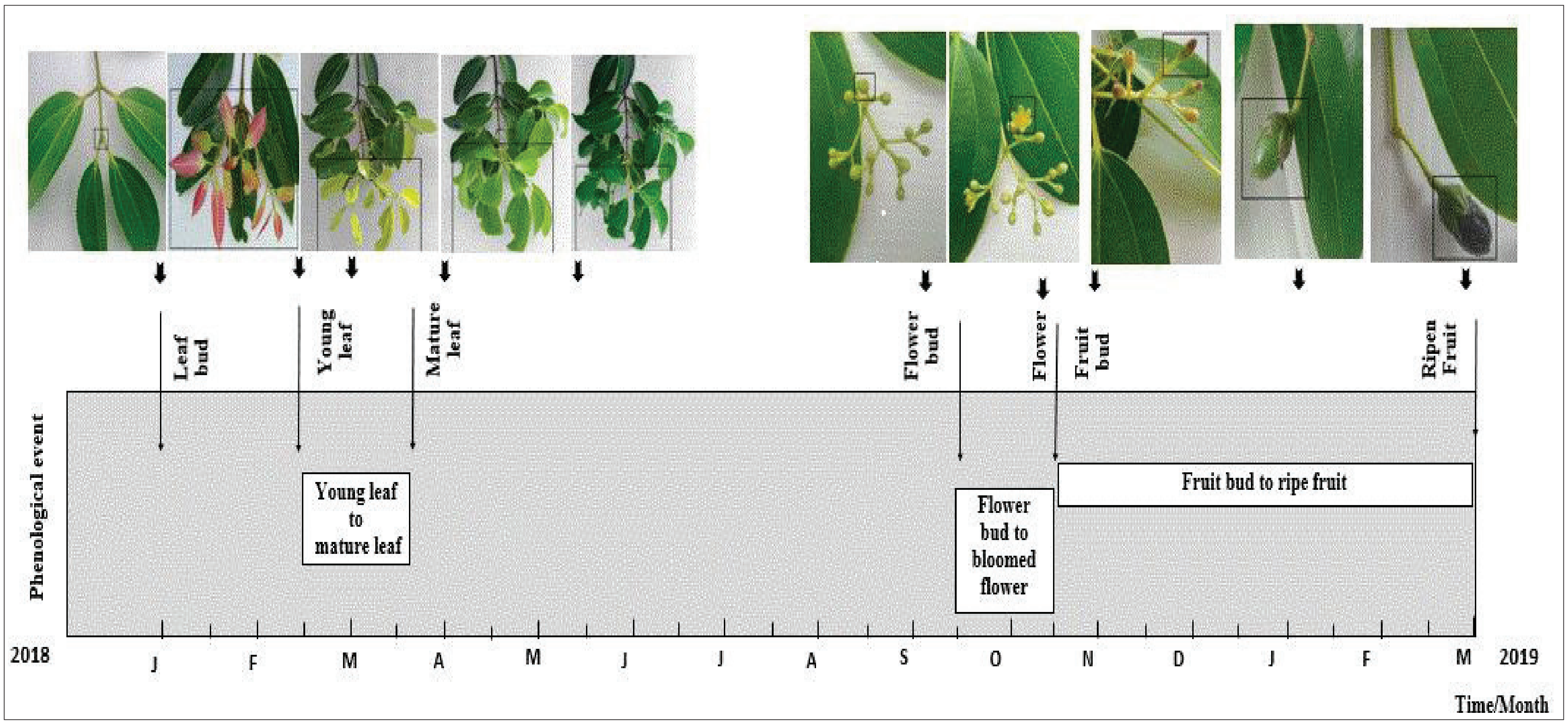

Figure 10: The graphical illustration of vegetative and reproductive phenological events of *Cinnamomum verum* over time. It shows the period of leaf bud formation, then leaf flush development, followed by development of flower buds, flowers, fruits and fruit ripening. Time period taken for each event is indicated by the box in the grey colour area and the image for each event is also given as a visual interpretation

have touched some aspects of the phenology of the same or other species of *Cinnamomum* conducted in other countries (Kasai *et al*., 2002 ; Singh & Kushwaha, 2005a ; Shivaprasad *et al*., 2015; Yulistyarini, 2020). Nevertheless, even such information may not be valid for *C. verum* growing in Sri Lanka as these details might represent completely different agro-ecological systems in other countries. As evidence, *C. verum* in Mahé Island, Seychelles, is considered as an aggressive alien invasive species (Fleischmann, 1999), the timing of the vegetative growth of which could be different from the non-aggressive and slow growth of *C. verum* in Sri Lanka.

The above behavior of phenological traits could vary depending on the variations in the agro-climatic region and soil factors etc. (Arntz *et al*., 1998). However, the behavior of phenological traits of *C. verum* is very important for the cinnamon industry in Sri Lanka, because we assume that the peeling ability of cinnamon positively correlates with the cambium activity. The higher cambial activity may enhance the peeling ability of cinnamon in two ways: firstly increasing the thickness of the cambial region with delicate cells between xylem tissue on the inner side and the phloem tissue. Secondly, an active cambium increases the thickness of the phloem tissue increasing the ability to get it peeled off, with minimum damage. Cambial activity may be greatly affected by variations in assimilate partitioning that could be decided by phenological traits. It is recognized that source-sink relationships in assimilate partitioning change with the developmental stage (Evans, 1991). Accordingly, it can be assumed that allocation of assimilates for the cambial activity may get reduced during the leaf flush, flowering, and fruiting in *C. verum*, reducing the ability to peel. The knowledge of phenology or the timing of recurring vegetative and reproductive events of *C. verum* revealed in this study are of utmost importance to proper timing and management of harvesting of cinnamon in Sri Lanka. Also this will lead to studies on how to manage the seasonal and environmental effect on peelability so that it could be useful to maximize the harvestable yield of *C. verum* in Sri Lanka.

CONCLUSION

Leaf emergence of *C. verum* in Sri Lanka displayed a mixed-multimodal pattern and one that takes place in flushes which appeared to be controlled by two factors, the inherent seasonality and the rainfall after a dry period. The seasonal flushing took place in the four months period from February to May. A leaf primordium took a mean number of 29.0 ± 8.5 days to become an opened leaf and leaves unfolded and then grew slowly increasing their size, reaching their maximum size in 57 ± 16 days. As evidenced from this study the leaf longevity of *C. verum* in Sri Lanka is longer than 15 months. The leaf fall was not continuous, and limited to a five-month period from March to July, with a peak in March.

Flowering in *C. verum* took place during October and November, however only 18.6 ± 5.6% of flower buds matured to flowers. Moreover, a mean number of 94.1 ± 8.5% of flowers developed into young fruits. The average number of fruits per branch was 7.5 ± 3.6. Fruit production peaked at the end of October, showing a unimodal response. When timing of flowering fruiting and fruit shed are considered, the six month period from September to March can be considered as the reproductive phase of *C. verum* growing in the study area.

Conflict of interest statement

There is no conflict of interest.

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