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Short Communication: Correlation of flowering phenology and heat unit of forest cloves (*Syzygium obtusifolium*) at different elevations in Maluku Province, Indonesia

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Abstract. *Kamsurya MY, Ala A, Musa Y, Rafiuddin. 2022. Short Communication: Correlation of flowering phenology and heat unit of forest cloves (*Syzygium obtusifolium*) at different elevations in Maluku Province, Indonesia. Biodiversitas 23: 5593-5599.* The phenology and heat unit of the forest clove (*Syzygium obtusifolium* L.) are important parameters for the efficient maintenance of this plant. This study aimed to describe phenological flowering stages (PFS) and calculate growing degree days for different PFS, which will have a big impact on crop management and understanding the impact of climate variables on crucial phenological events. The research was conducted in Ambon, Maluku Province, Indonesia, for 16 months, from January 2020 to May 2021. Five sample points at different elevations were determined purposively, i.e: Halasi (6 m above sea level (m asl)), Tibang (11 m asl), Oli (125 m asl), Wanat (175 m asl), and Telaga Kodok (214 m asl). The phenology of flowering is separated into 6 stages: the flowering primordia, the appearance of the flower stalk, the perfect flower stalk, the appearance of the flower bud, the flower is fully formed, and the flower starts to bloom. The results showed that the phenological cycle of the forest clove plant was flowering periodically for 365 days. The average temperature of PFS (29^{o}C) in Halasi was higher compared to other locations. It indicates that the lower the altitude, the faster the flowering period. This study found significant correlations between altitude and PFS, except flower stalks appear and flowers will appear. The phenology of clove plants is influenced by the accumulation of heat units, with the highest heat unit value in the flowers start to bloom stage, ranging from 2,983.23 days^{o} (Telaga Kodok) to 3,128.84 days^{o} (Halasi). As elevation increases, the number of heat units decreases, so the PFS is delayed. The primordial phase in Halasi appears in August-September while at Telaga Kodok in December.

Keywords: Altitude, flowering, forest cloves, heat unit, phenology

INTRODUCTION

Cloves are an endemic plant of Indonesia that grow naturally from the shoreline far into the mountain. This plant has an important meaning in being produced to meet domestic demands as raw materials for the cigarette industries (Mittal et al. 2014), medicinal ingredients (Abdullah et al. 2015), and food preservatives (Hussain et al. 2017). Several germplasm diversity of cloves was found in Indonesia, which consist of landrace, primitive, wild, and commercial types (Koerniati 1997).

The forest cloves (*Syzygium obtusifolium* L.) are wild cloves that grow in the forests on Ambon and several other islands in Maluku, such as the islands of Seram, Buru, Lease (Alfian et al. 2019), Hiri (Suparman et al. 2018), and Haruku (Mahulette et al. 2022). Cloves are also one of the essential oil producers which can be used as raw material for the pharmaceutical industry. The population of forest cloves has decreased, so it is needed to cultivate this plant in the Ambon and its surroundings for the past few years. With the existence of cultivation activities as well as an in situ conservation effort. The conservation of species in their natural habitats is regarded as the most effective method of conserving biodiversity. One of the considerations of farmers in cultivating forest cloves is the primordia stage can reappear due to the relatively short flowering period ranging from 7-8 months from harvest. Besides that, the area of leaves of forest clove is larger than other clove types. Farmers on the islands of Ambon and Maluku generally say that this clove plant can bear fruit every year. In contrast to aromatic cloves such as siputih, sikotok, Zanzibar, and Ambon, the fruiting period after harvesting is relatively longer.

The phenology of flowering is one of the important characters of the plant life cycle. Because in that stage, the initial process occurs for a plant to reproduce. A plant has different behavior in flowering and fruiting but generally begins with the appearance of flower buds and ends with fruit ripening. The continuity of these stages is strongly influenced by the surrounding environmental conditions, such as the length of irradiation, temperature, and humidity. Phenology is related to changes in growth, development, flowering, and the maturation of seeds/fruits of plants. Each stage in plant growth requires a certain time that differs from one stage to another. Plant phenology can be used as an indicator to explain changes in environmental

conditions (Workie and Debella 2018). It also serves as a vital indicator of plant physiological expression in response to climatic change. As a result of its sensitivity to weather variables, phenology is regarded as one of the essential research topics (Tang et al. 2016).

Temperature variations in tropical areas are caused by varying altitudes above sea level. The higher the growing site (altitude), the longer the plant lives. To examine the effect of temperature on flowering phenology, the general concept used is the degree day or heat unit. The heat unit is the amount of heat a plant requires to reach the development level during harvest time. The heat unit is a concept of calculating the unit of heat every day, which depends on the daily average temperature and the basic temperature of each plant. Conversely, if the air temperature is below the base temperature of the plant, the metabolic rate that occurs will stop so that the results will know the effect on the development of these plants.

Information on the PFS of forest clove plants has not available. Therefore, the study aimed to describe phenological flowering stages (PFS) and calculate heat unit (HU) for different PFS, which will understand the impact of climate variables on crucial phenological events and then, will have a big impact on crop management.

MATERIALS AND METHODS

Study area

The research was conducted in Ambon, Maluku Province, in the eastern part of Indonesia. Field research was carried out for 16 months, from January 2020 to May 2021. The location sampling site was located in 5 locations, i.e., Halasi with an altitude of about 6 m asl (3°30'37" S 128°14'15" E), Tibang 11 m asl (3°35'00" S 128°10'40" E), Oli 125 m asl (3°35'27" S 128°10'39" E), Wanat 175 m asl (3°36'37" S 128°11'16" E), and the location of Telaga Kodok 214 m asl (3°37'11" S 128°10'55" E) (Figure 1).

Morphological characteristics analysis

The sampling was done using purposive samplings (Moleong 2018). At each location, 10 sample plant trees choose to represent the condition of the plants growing and developing in their entirety for all forest clove plant populations. The selected plants have an age ranging from 10-15 years. The flowering stage of clove was observed starting from flowering primordia, appears flower stalks, the perfect flower stalk, flowers will appear, flowers are perfectly formed, and flowers start to bloom (IPGRI, 1980). Furthermore, the calculation of the period of each flowering stage and the shooting for the documentation were conducted.

Data analysis

The phenological stages of forest clove, starting from the flowering stage until flowers start to bloom, are presented in the form of figures and then analyzed descriptively. Observational data was tabulated, and then the regression relationships between altitudes and the phenological flowering were performed with Excel.

The heat unit (HU) was calculated by using the following formula according to Cross and Zuber (1972):

$$HU = \left(\frac{Tmax - Tmin}{2}\right) - Tbase$$

Where: TMAX is the daily maximum air temperature, TMIN is the daily minimum air temperature, and TBASE (10°C) is the temperature below which the process of interest does not progress (Brown 2013).

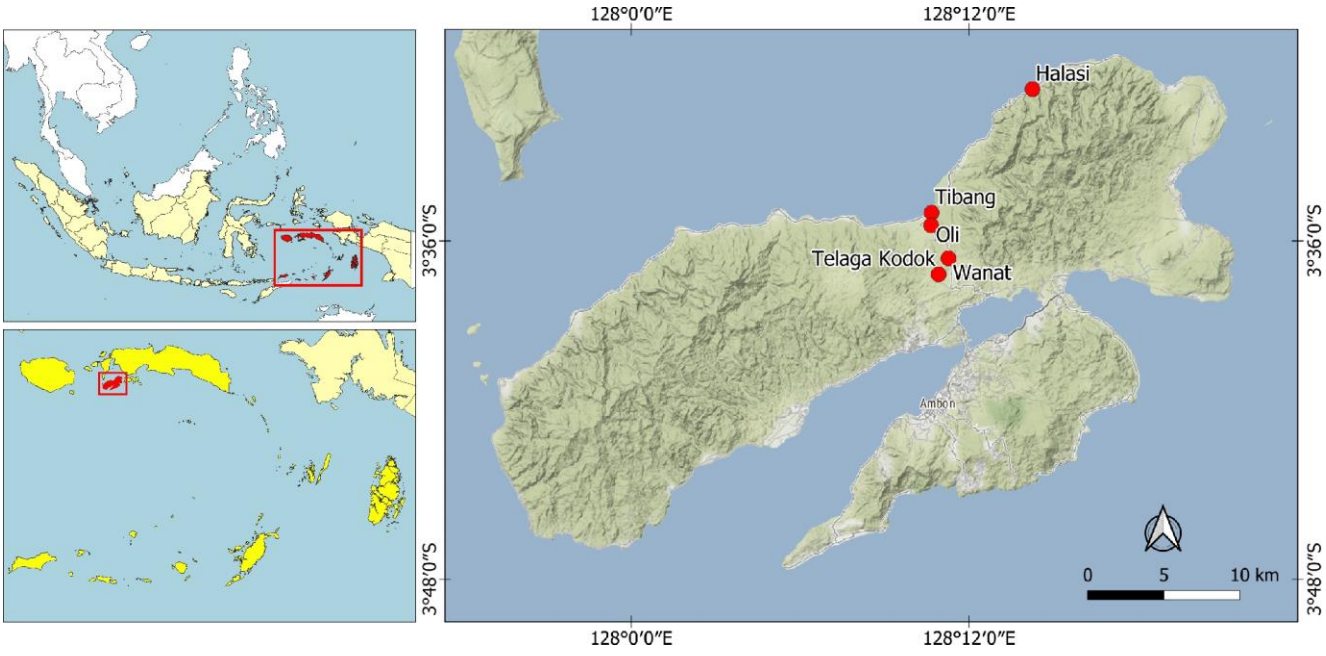

Figure 1. Research location in Maluku, Indonesia

RESULTS AND DISCUSSION

Flowering phenology

The phenological flowering stages are presented in Table 1. The primordia stage started with the emergence of shoots for about 24.5-29.2 days, and then leaves were formed. After the number of leaves is 5-6 strands, the tip of the shoot stalk begins to enlarge, indicating that the primordia period was begun. This stage is the longest in the flowering cycle of forest clove.

The second stage started at the end of the flower primordia until the appearance of the flower stalk (Figure 2B). This stage lasts about 27.1-28.4 days after the flowering primordia. The third stage started with the flower stalk formed until the flower stalk was fully developed (Figure 2C). This stage lasts about 26.1-28.4 days after the flower stalk formation. The fourth stage, which is the stage that begins when the flower stalk is fully formed until the flower buds appear, takes about 26.6-27.9 days (Figure 2D). The fifth stage, where the flowers are formed, has been perfect, with a duration of about 27.8-29.1 days (Figure 2E).

The sixth stage, namely the flowers start to bloom, is a stage that starts from the maximum size of clove flowers (Figure 2F). This period lasts until a few flowers begin to bloom. This time is a good harvest period, namely clove flowers that bloom about 3-10 percent. The duration of this period in a population of flowering trees lasts about 29-32 days. Most clove flowers have not reached their maximum size if they are done too early. If harvesting is delayed where most of the flowers will bloom, at that time, stamens and flower petals will easily fall. Thus, harvesting that is too early or delayed can affect the quality and quantity of crop yields. According to Darwati (2018), the flowering of cloves in Indonesia is not the same in all regions. This is due to differences in climate and altitude.

Relationship of place elevation with flowering phenology

In this period of cloves, there are two main phases, namely the vegetative and generative phases. This generative phase begins with the flowering primordia until the flowers start to bloom. It has been described that there are six phases in the flowering phenology of forest clove plants, the overall duration of which is relatively not different, which is around 165.3-168.7 days.

Figure 1. Flowering phenology of forest clove plants, A. Primordia; B. flower stalks appear; C.Perfect flower stalk; D. Flowers will Appear; E. Perfectly formed flowers; F. Flowers start to bloom

The flowering started to bloom from the first week of January to the second week of May. Thus, the time required for the harvesting period of forest clove was about 119 days. If this length of time is associated with the highest altitude in this study (214 m asl), then the average time shift for every 1 m asl addition will result in a delay of harvest time of 0.57 days, equivalent to 13.73 hours. Delay in the harvesting period with the higher elevation of the most prominent place, when there is a change in altitude from 6 to 125 m asl where every time there is an increase in the height of 1 m asl, then harvesting delays will shift for 0.59 days, equivalent to 14.16 hours. In contrast to the change in harvest time at an altitude of 125 m asl to 214 m asl, the height difference is 89 m asl. At the same time, the delay in harvesting is only about four weeks (28 days). This means that for every 1 m increase in altitude, there will be a 0.31-day delay in harvesting, equivalent to 7.44 hours. Thus, by increasing the altitude from 6 to 125 m asl, the delay in harvesting is up to 2 times slower than the increase in altitude from 125 to 214 m asl.

This study found significant correlations between altitude and PFS, except flower stalks appear and flowers will appear (Figure 3). Negative correlations were found between altitude and perfectly formed flowers. It indicated that the lower temperature, especially cold temperatures in higher latitudes regions, might result in the prematurity of clove and thus the shorter reproductive period.

Temperature and heat unit

Temperature is one environmental factor that affects the development of forest cloves. Temperature affects the process of photosynthesis and plant respiration (Dusenge et al. 2019). The distribution of temperature, which has a considerable impact on the duration of crop development. Clove plants generally grow from the lowlands to the highlands at an altitude ranging from 0-900 m above sea level. If the air temperature is high or low, it will interfere with photosynthesis and respiration reactions, affecting plant development. According to Hasanuzzaman et al. (2013), the temperature can control biochemical reactions, physiology, and the stability of plants' enzyme systems. In addition, the temperature can also affect several plant growth and development processes such as respiration, auto synthesis, dormancy, flowering, and fruit formation. Low temperatures cause the rate of photosynthesis to be slow, resulting in a slow rate of growth and development. If the air temperature around the plant is too low or high, it can inhibit flower development so that fruit quality becomes low, hampers harvest time, and reduces crop production. Environmental factors will influence the pattern and productivity of flowers and fruits through shifting flowering and fruiting seasons (Winarni et al. 2016), especially specific microenvironments to plant growth (Adole et al. 2016; Panchen 2016).

In the present study, the temperature of PFS in Halasi was higher compared to other locations (Figure 4). High temperatures near maturity might have induced modifications in plants, which is apparent from the change in existing physiological processes or from the altering development pattern. These responses may differ from one phenological stage to another. The effect of temperature changes in accelerating flower appearance was also explained by Dorji et al. (2020) based on the results of research conducted on alpine meadows in the Central Tibetan plateau, it was found that there was a significant warming effect in advancing the time of the appearance of the first flowers of several types of grasses. The influence of climate and temperature on flowering phenology was also explained by Du et al. (2020) and Medina-Alonso et al. (2020).

Table 1. The flowering period of forest clove at different locations

Location	Phenological stage	Duration (Days)	Total duration (days)	Period
				2020: August, September, October, November, December; 2021: January, February, March, April, May
Halasi (6 m asl)	Primordia	25.2	167.7	
	Flower stalks appear	28.2		
	Perfect flower stalks	27.3		
	Flower will appear	26.6		
	Perfectly formed flower	28.8		
	Flowers start to bloom	31.8		
Tibang (11 m asl)	Primordia	24.5	166.8	
	Flower stalks appear	27.6		
	Perfect flower stalks	26.5		
	Flower will appear	26.7		
	Perfectly formed flower	29.1		
	Flowers start to bloom	30.9		
Oli (125 m asl)	Primordia	27.3	167.0	
	Flower stalks appear	27.1		
	Perfect flower stalks	28.4		
	Flower will appear	27.4		
	Perfectly formed flower	28.3		
	Flowers start to bloom	30.2		
Wanath (175 m asl)	Primordia	29.2	168.1	
	Flower stalks appear	28.4		
	Perfect flower stalks	26.7		
	Flower will appear	27.3		
	Perfectly formed flower	27.8		
	Flowers start to bloom	28.8		
Telaga Kodok (214 m asl)	Primordia	29.8	168.2	
	Flower stalks appear	26.5		
	Perfect flower stalks	26.1		
	Flower will appear	27.9		
	Perfectly formed flower	27.9		
	Flowers start to bloom	29.2		

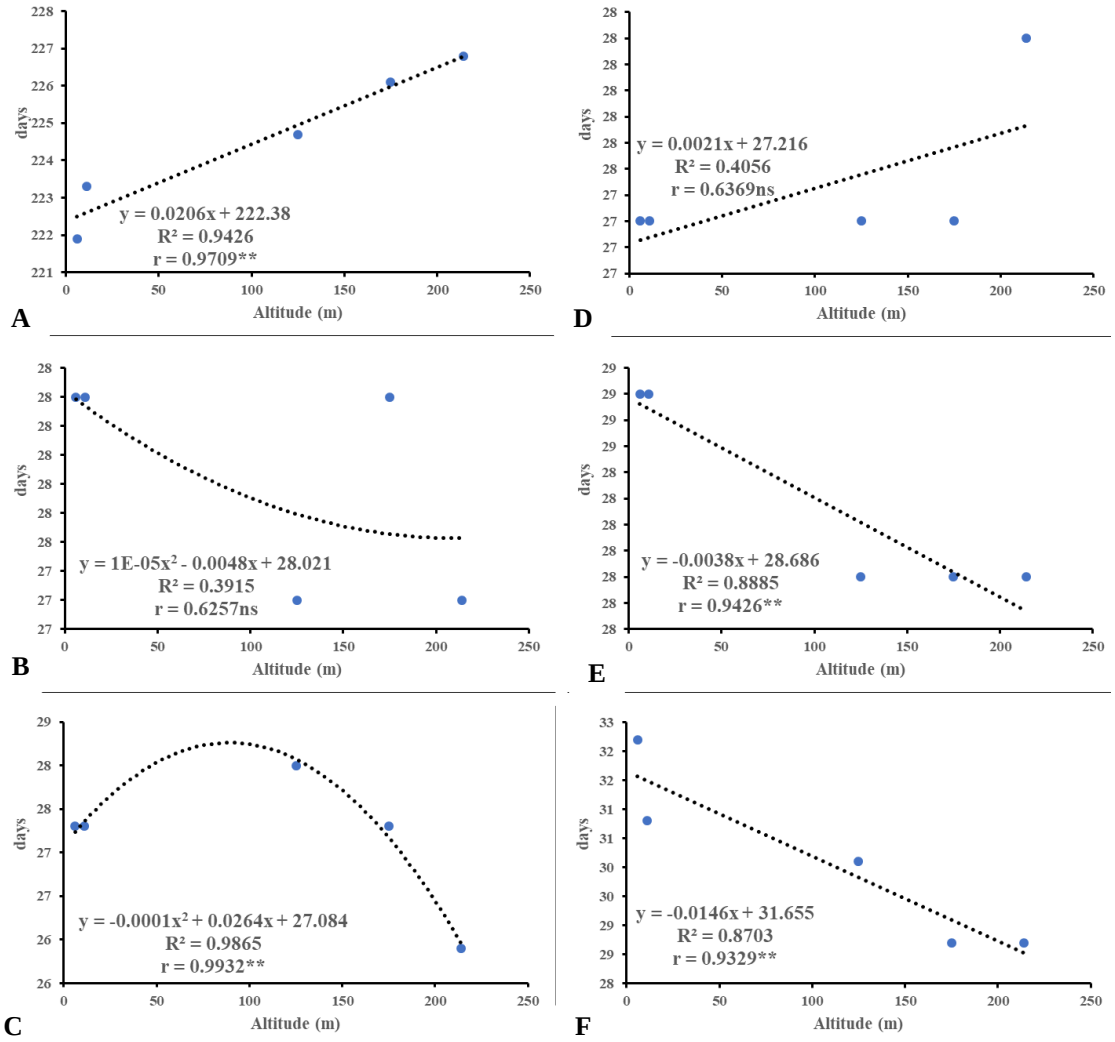

Figure 3. Regression model. This model is for the relation between altitude and phenological stage, A. Primordia; B. flower stalks appear; C. Perfect flower stalk; D. Flowers will Appear; E. Perfectly formed flowers; F. Flowers start to bloom.*Significant at 5% level, **Significant at 1% level

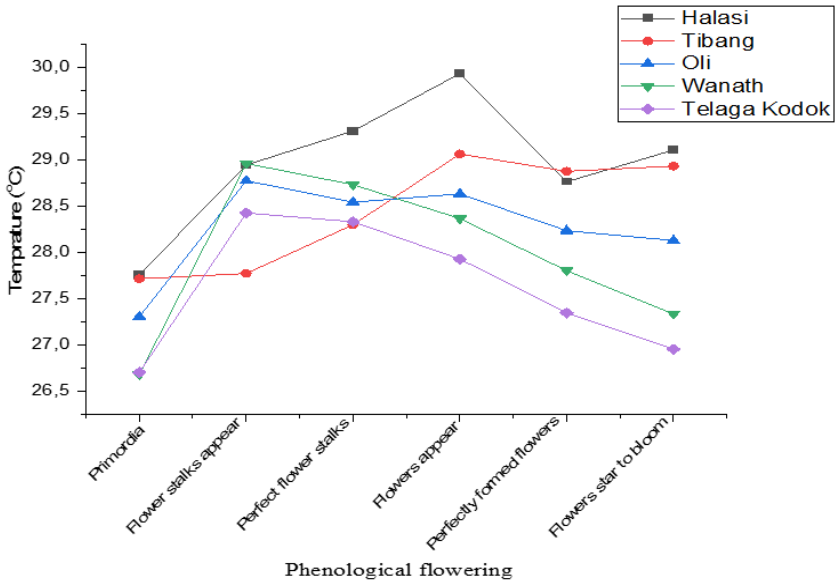

Figure 4. Temperature for each location based on every phenological stage

Table 2. Heat unit on the phenological flowering stage of forest clove

Phenological flowering stage	Heat unit (days°)				
	Halasi	Tibang	Oli	Wanath	Telaga Kodok
Flowering primordia	391.74	467.50	498.56	544.77	575.69
flower stalks appear	922.24	965.16	1,005.55	1,066.40	1,061.07
Perfect flower stalk	1,443.69	1,459.29	1,511.10	1,556.62	1,528.41
Flowers will appear	1,981.94	1,994.04	2,009.58	2,069.07	2,038.59
Perfectly formed flowers	2,525.69	2,539.90	2,532.07	2,549.82	2,510.56
Flowers start to bloom	3,128.84	3,126.25	3,060.20	3,044.94	2,983.23

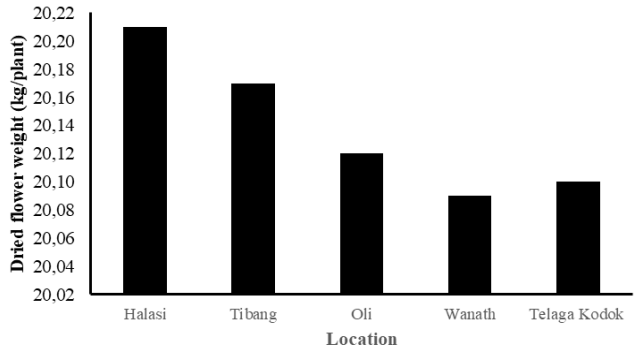

Figure 5. The yield of dried flowers for each location

According to Campanella et al. (2020), concerning the stages in plant development, there is a strong relationship between plant phenology and environmental variables. A strong relationship between plant PFS occurs with soil moisture content and air temperature compared to rainfall. Air temperature is related to altitude. Whereas the altitude increases, the air temperature decreases. Hart and Salick (2018) stated that the reproductive output of plants is influenced by phenology, with higher flower and fruit numbers in plants that flower slightly earlier than the population average, and plants that respond to warm weather will bloom earlier.

Heat unit is a critical factor in influencing crop growth and development under various temperature regimes (Meena and Rao 2013). It correlates plant growth, development, and maturity to the specific HU requirements of each phenological stage (Parthasarathi et al. 2013). The need for heat units in each stage of the clove plant based on the research results is different. Details of the heat unit values are presented in Table 2. The highest heat unit value was in the flowers start to bloom stage, ranging from 2983.23 days° (Telaga Kodok) to 3,128.84 days° (Halasi) (Table 2). The calculation of accumulated heat units, as shown in Table 2, shows that to enter the growth stages, clove plants require different heat units of energy. Early flowering is caused by the accumulation of a deficit of heat units at flowering. Flowering is delayed as a result of excessive heat unit buildup during flowering. The heat unit value in the lowlands is greater than in the highlands. The reason is that the temperature in the low land is higher than in the highlands.

The production of forest clove plants was indicated by the variable weight of harvested flowers in dry conditions (Figure 5). The results of the analysis show that with increasing elevation, the yield of dried flowers tends to decrease. This is because the water content of the flower increases with increasing elevation, where the water content ranges from 59.9 - 63.5%.

Our findings on phenology and the heat unit of forest clove are crucial for planning cultivation at the study site and in other places with similar climatic conditions, as they allow for harvest prediction. The most important stage of the PFS was flowers start to bloom. Increasing air temperature conditions to a certain extent, affect the flowering phenology of forest clove plants. The good predictive capability of the algorithms suggested for being tested for estimating the effect of environmental factors on forest clove phenology.

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