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## Effect of heat units and time duration required for maturation of mango (*Mangifera indica* L.): A review

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### Abstract

**Background:** Mango is the world's most popular tropical fruit. It's high in a variety of nutrients and has a long list of health advantages. The best quality mango with excellent ripeness, texture, and aroma is preferred by the majority of consumers. Mangoes must be picked at the proper time by detecting different maturity indices such as peel colour, pulp colour, fruit firmness, fruit size, and total soluble solids and it entails destruction of fruit. For computing approaches such as heat units and time duration the fruit destruction is not a requisite. Heat units are the number of degrees above a specified threshold (base) temperature (i.e., 10 -17.9 °C for mango) throughout the course of a 24-hour period. Degree days are used to determine heat units.

**Result:** Each type of mango needs a different number of heat units. Mango maturation is directly determined by the quantity of heat units and length of time it takes to reach harvest. The fruit will not ripen adequately if it is harvested before it reaches maturity. If it is harvested late after it has become overripe its postharvest quality and shelf-life are reduced. As a result, fruits picked at the correct time have better physical characteristics and quality attributes, making them more marketable.

**Keywords:** Maturity indices, heat units, time duration, mango, quality

### Introduction

Mango (*Mangifera indica* L.) is a major tropical fruit relished all over the world (Chonhenchob *et al.* 2010; Fahimdanesh and Bahrami, 2013; Kaushik *et al.* 2016) [9, 11, 24]. It is an evergreen tree and one of India's predominant fruit crops belonging to genus *Mangifera* falling under Anacardiaceae family (Farina *et al.* 2020) [13]. The genus *Mangifera* consists of about 30 species of fruiting trees (Shah *et al.* 2010) [45]. The origin and centre of diversity of this genus lies between North-Western Myanmar, Bangladesh, and North-Eastern India (Sharma, 2021) [46]. Internationally it is recognized as the ambassador fruit of India and it is considered to be the "King of fruits" and "National Fruit of India" (Kavitha *et al.* 2022) [25]. Mango is preferred globally owing to its convincing taste with high nutrition (Kanzaria *et al.* 2015; Halepotara *et al.* 2019) [21, 17]. Worldwide, more than 56 million tonnes of mangoes were produced in 2019, of which 46% were produced in India (FAOSTAT, 2021) [12]. India, being the biggest producer of mango in the world with 2.3 million hectares in area and 20.5 million tonnes in production (Anonymous, 2020) [3]. Mango is an excellent source of minerals such as calcium and iron, as well as critical vitamins such as vitamin A and vitamin C. The fundamental nutritive content of mango fruit varies depending on the cultivar (Gentile *et al.* 2019; Akin-Idowu *et al.* 2020) [14, 2].

Flavour, aroma, texture, chemical contents, and antioxidant capabilities are all important factors in consumer acceptance of high-quality fresh mango (Rymbai *et al.* 2013) [42], and they all depend on the fruit's maturation level. This crop is grown in over a hundred different types, each with its own size, shape, sweetness, skin, and flesh colour. Alphonso, Amrapali, Banganpalli, Dashehari, Himsagar, Ratna, Mallika, and other cultivars are popular in India's many mango growing regions (Sharma, 2021) [46].

It is critical to put the time and effort to find the right ripening stage for harvest. The quality and shelf life of mango fruit after harvest (like with all other fruits) are greatly influenced by the degree of ripeness at the time of harvest (Zagade *et al.* 2014; Anusuya *et al.* 2016) [55]. To get greater quality and a longer shelf life, fruit must be picked at the right time. If the fruit is picked too early, it may not ripen correctly after being picked, or it may not even be ripe. If the fruit is harvested when it is fully mature, it may have certain defects or have a shorter shelf life (Le *et al.* 2022) [27].

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A fruit is considered to be matured when it achieves some major indicative parameters. Those parameters are estimated through different methodologies and are called 'Maturity indices.' Some indices require destruction of fruit while others are non-destructive methods. Maturity indices can be grouped into the following categories as given by Ramjan *et al.* (2017) and Jacinta (2013)<sup>[40, 19]</sup>.

1. Physical maturity index
  - Colour of the peel and pulp
  - Specific gravity of fruit
  - Size of fruit and other sensory analysis
  - Density of the fruit, etc.,
2. Bio-chemical maturity index
  - Total Soluble Solids
  - Sugar and acid ratio
  - Nutritive value, etc.,
3. Computational methods
  - Time duration from first fruit set to harvest date
  - Heat Unit Indices accumulated in the fruit– like Growing Degree Days, Helio Thermal Units, etc.,

Other methods include evaluation of physiological changes and shoulder development. Halepotara *et al.* (2017)<sup>[18]</sup> highlighted the practice of determining a fruit's maturity, when the first fruit starts falling from the tree, it is considered as a symbol of fruit maturity and the phenomenon is called 'Tapka.' Farmers started harvesting fruits after Tapka.

Calculative techniques, which are among the several methods listed above, have been extensively used by farmers for many years since they do not entail any physical disturbance of mango fruits (as opposed to biochemical approaches, which require laboratory operations). When a 24-hour period is observed, the number of temperature degrees over a defined threshold (base) temperature is referred to as growing degree days, heat units, or thermal units.

René Antoine Ferchault de Réaumur, an eminent French Entomologist, is credited with conducting the first quantitative research on the relationship between plants and temperature (Réaumur, 1735; Streck, 2004)<sup>[41, 36]</sup>. Growing Degree Days (GDDs) or Heat Units, are a unit of measurement used in agriculture. Heat units are calculated by using the formula (Zagade *et al.* 2014)<sup>[55]</sup> as follows,

$$HU = \sum [(T_{\max} + T_{\min})/2] - T_{\text{base}}$$

#### Where

- HU = Heat units (°C);
- $T_{\max}$  = Maximum daytime temperature (°C);
- $T_{\min}$  = Minimum daytime temperature (°C) and
- $T_{\text{base}}$  = Minimum growth temperature.

For mango the base temperature is 17.9 (Oppenheimer, 1947)<sup>[37]</sup> threshold temperature. The base temperature was considered as 17.0 °C instead of 17.9 as reported by Yahia (1999)<sup>[54]</sup>.

#### Effect of Heat Units and Time duration required for mango maturation

Taking advantage of the opportunity to pick fruits before they are fully developed, at any point after the stone has formed, is helpful since it may reduce pre-harvest fruit drop and post-

harvest spoilage (Lakshminarayana, 1973; Musale and Patil, 2014)<sup>[43, 35]</sup>. Each genotype of mango needs certain amounts of accumulation of heat units for completion of different phenophases which cause the variation in maturity period (Singh *et al.* 1998, Malik *et al.* 2014)<sup>[50, 31]</sup>. Stanley *et al.* (2000)<sup>[51]</sup> mentioned that the contribution of weather to fruit demand could be associated with the daily variation in degree days used to compute fruit demand. Temperature, humidity, and bright sunshine hours are the most important factors affecting plant life after soil, moisture and nutrients (Mathieu, 2006)<sup>[34]</sup>. Heat Units play a momentous role in mango maturation process (Sarakosh *et al.* 2018)<sup>[44]</sup>.

#### Effects of Heat units required for mango maturation

Rai *et al.* (2003)<sup>[39]</sup> carried out extensive research in 71 genotypes of mango in Eastern India to study the total heat units vital for fruit maturity. Cultivars have also been grouped into five categories based on GDD (Growing Degree Days) namely, Group 1 consisted of cultivars that need less than 1800 °C, Group 2 demanding 1800 to 2000 °C, Group 3 requiring 2000 to 2400°C, and Group 4 requiring more than 2400 °C,. 71 cultivars under consideration were grouped into five broad groups based on their maturity date *viz.*, very early, early, medium, late and very late maturing genotypes.

Zagad Peel colour is one of the peculiar characters that changes during each stage of fruit development. The peel colour of mango increased with increased time duration for harvest. The highest amount of heat units received by the variety Alphonso for fruit maturation was 1072.75-degree days, recorded in the mango fruit harvested at 135 days after fruit setting (DAFS). Based upon the organoleptic behaviour, Alphonso is harvested at 120 DAFS. The change in peel colour of mango is depicted in (figure1).

The influence of external temperature and rainfall during the vegetative and reproductive stages of mango were well established. Alphonso develops spongy tissues due to high temperature (Makhmale *et al.* 2016)<sup>[29]</sup> But, during the reproductive stage, Harumanis require a dry and hot atmosphere combined with little rainfall (Talib *et al.* 2020)<sup>[53]</sup>. Shetty *et al.* (2022)<sup>[47]</sup> evaluated maturity indices of south Indian mango varieties for determining heat units and harvesting time. They found that early maturing (110 DAFS with 1107.75 HU) variety Ratna had deposited less HU than late maturing (140 DAFS with 1507 HU) variety Mallika.

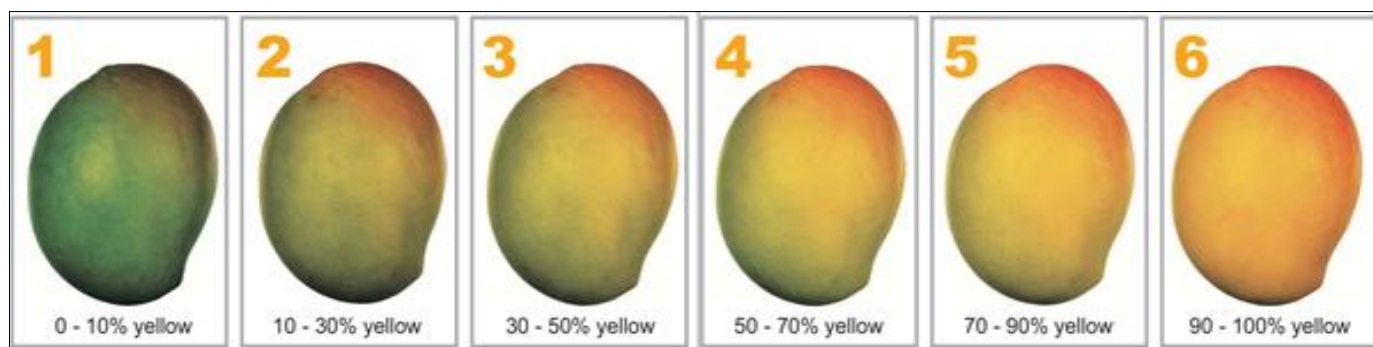
Mango fruits mature earlier in lateritic areas than in other areas because the requisite heat units are completed in a shorter time (Malshe *et al.* 2020)<sup>[32]</sup>. Mango orchards that are located nearby the sea at Konkan coast were also experienced robust and early fruiting (Mahadik *et al.* 2021)<sup>[28]</sup>. An example to the above statements were clearly noted by (Shinde *et al.* 2001)<sup>[48]</sup>. At Rameshwar, early fruit maturity was reported in mango cultivation. So, to find the cause of early maturity of mango fruits, the total heat unit requirement for the selected cultivars was estimated. Due to extra heat units produced in Rameshwar for the aforesaid types, the fruits of Alphonso, Kesar, and Ratna mature 23.33, 24.33, and 20.50 days sooner at Rameshwar than Vengurle, respectively. Kanzaria *et al.* (2022)<sup>[22]</sup> concluded that heat unit indices like Growing Degree Days (GDD), Helio Thermal Units (HTU) and Photo Thermal Units (PTU) had a direct impact on mango fruit maturation. Among the cultivars taken into account, Kesar matured early at 98.40 days and a heat unit accumulation of 1051.60 GDD but, in case of Halepotara *et*

al. (2019) <sup>[17]</sup>, Mango fruits of kesar variety harvested at 105 days of fruit set (T5) with accumulation of 1020 HU was found to be the best. The differences in heat units and period of maturity for same variety may be due to the environmental factors of two diverse locations.

In order to mitigate abiotic stresses, Adak *et al.* (2017) <sup>[1]</sup> emphasised the need of calculating heat unit requirements for cultivars. They focused at HU, as well as energy and water use efficiency, in three seasons of Dashehari mango. The higher heat and water use efficiency was recorded when 75% of recommended doses of fertigation was given.

Extra Heat unit deposition might lead to increased cell

division, thereby fasten the physiological activities of mango (Gole, 1986) <sup>[16]</sup>. Some studies depict high temperature can cause mango softening in types like Dusheri, 948.45 to 1081.50 Degree Days is the required heat unit at minimum and also 10.64-10.99 Degree Days as mean units on daily basis were vital for harvesting superior quality Dashehari fruits (Singh *et al.* 2011) <sup>[49]</sup>. Experiments were conducted in understanding dynamics of mango hopper behaviour and the relationship between hopper population and GDD were established. The population of hopper can be predicted up to 66% using Heat Unit indices (Gundappa *et al.* 2018) <sup>[7]</sup>.



Source: <https://khanhhoafood.com/faqs-mango>

Fig 1: Change in peel colour of mango

#### Effect of time duration required for mango maturation

Mango continues to ripe even after harvest (climacteric fruit) (Gundewadi *et al.* 2018). So, they tend to get susceptible to post-harvest diseases and their shelf-life quality will be depleted. Mangoes should be harvested from the tree at proper time according to the market requirements. Subedi *et al.* (2007) <sup>[52]</sup> explained the difference between mature and immature mangoes. The fruits with best eating quality are considered mature and are acceptable by consumers. Hence, it

is important to calculate the time duration from fruit set to the maturation of mango for every variety and determine the best harvest time. The preference of end users changes according to markets located at different localities. Consumer acceptability is inevitable for the success of any variety and for creating huge profits to the mango growers. It was disclosed that mangoes collected between 126 and 133 days after full bloom had higher consumer acceptance (Gianguzzi *et al.* 2021) <sup>[15]</sup> Table (1).

Table 1: Heat Units and Time Duration required for mango maturation for some cultivars

S. No.	Name of the Variety/ Hybrid	Number of days for maturity (days)	Amount of Heat Units accumulated (DD)	Reference
1	Alphonso	135	1072.75	Zagade <i>et al.</i> 2014 <sup>[55]</sup>
		93	701	Burondkar <i>et al.</i> 1999.
		104.58	1161.22	Kanzaria <i>et al.</i> 2022.
2	Kesar	95.88	1062.71	Kanzaria <i>et al.</i> 2015.
		97.65	1123.83	Kanzaria <i>et al.</i> 2022.
		118	773	Burondkar <i>et al.</i> 1999
3	Ratna	110	1107.5	Shetty <i>et al.</i> 2022 <sup>[47]</sup>
		127	849	Burondkar <i>et al.</i> 1999.
4	Mallika	140	1507	Shetty <i>et al.</i> 2022 <sup>[47]</sup>
5	Jamadar	104.33	1129.25	Kanzaria <i>et al.</i> 2022.
6	Dudhpenda	112.75	1205.38	
7	Dashehari	-	1509	Adak <i>et al.</i> 2017 <sup>[1]</sup>
8.		-	1081.50	Singh <i>et al.</i> 2011 <sup>[49]</sup>
9	Krishna Bhog	120	1678.57	Rai <i>et al.</i> 2003 <sup>[39]</sup>
10	Raspuri	150	1913.14	

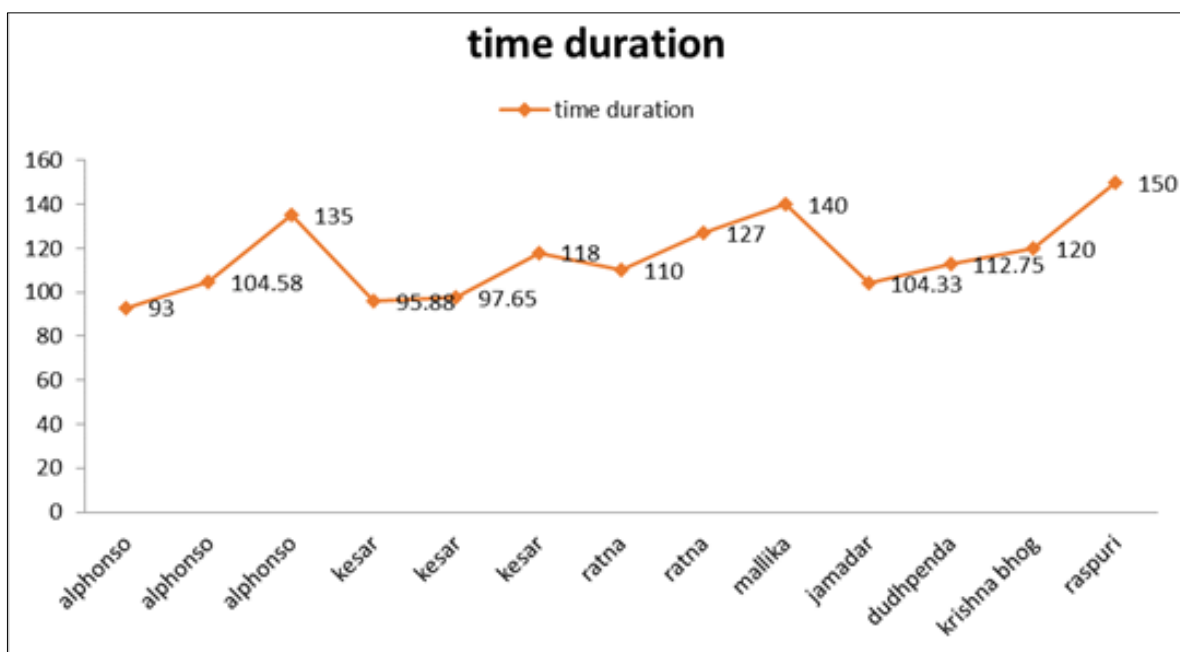


Fig 2: Time duration required by different mango for maturation (in days)

State upon harvest. Fruits picked at a younger stage of maturity retain green for a long period before ripening, in contrast to those picked later (Baldwin *et al.* 1999, Paul *et al.* 1997 and Dick *et al.* 2009) [5, 38, 10]. If the fruit is used for export purposes, basically the fruits are harvested at early stages of maturity.

Time duration for harvest will also influence physio-chemical characteristics. Mangoes harvested from 94 to 100 days after full flowering was advised. Those fruits had light yellow or orange peel with sweet taste attributed to content of sugar (up to 10 ° Brix at harvest and 14.2 to 20 °Brix after harvest) of mango indicating the fruits attaining physiological maturity (Dick *et al.* 2009) [10]. The principal indicator of mango quality and post- harvest storage was identified to be harvest ripeness. (Jha *et al.* 2007 and Kaur *et al.* 2015) [20, 23]. Halepotara *et al.* (2017) [18] commented that the rate at which ripening occurs under particular storage conditions will depend upon the stage of ontogeny at harvest. More mature fruit will ripen more rapidly than less mature fruit. The best time duration for Indian mango Dasher based on quality was 111 days succeeding fruit set (Kour *et al.* 2018) [26].

Tree ripe mangoes or ready to eat mangoes are the ones which are not harvested at commercial ripeness but harvested after fully ripened in the tree itself. The tree ripe mangoes are highly preferred in European markets due to its high Vitamin – C and Vitamin – A content (12.99 and 0.854 mg/ 100 gm respectively in Tommy Atkins variety) (Farina *et al.* 2020) [13]. Analysis for nutraceutical contents, physical analysis and sensory analysis were carried out by Farina *et al.* (2020) [13], identifying cultivars with better fruit firmness even after completely ripen stage. The fruits harvested at 80 days after initiation of fruit set have higher vitamin-C content whereas the harvest at 110 days resulted in higher sugar content (Baloch *et al.* 2012) [6]. The physical parameters, quality parameter, time taken to maturity, marketable fruits, and fruit spoiling in mango cv. Kesar were strongly influenced by the varied time periods taken for maturity, according to the findings of (Halepotara *et al.* (2018).

Phenolic acids in mango provide major dietary advantages.

Acids like ferulic acid, chlorogenic acid, etc., were found in mangoes (Maldonado-celis *et al.* 2019) [30]. Mango fruits harvested at a time where these phenols are highly present is essential. The phenolic content decreased with progression of ripening, in contrast, the carbohydrate content increased along with ripening. Hence, for people with diabetes, stage 2 of ripening is considered for consumption (Mandal *et al.* 2020) [33].

## Conclusion

Maturity indices play a major role in harvesting mango fruits at right time. Heat Unit is one of the ways to identify appropriate fruits for harvest. The heat units accumulation or the growing degree days is a basic necessity for initiating, progressing and completing the stages of maturity of a mango. Climate change is one among the important factors that influence agricultural production. So, it is necessary to evaluate the harvest time periodically with the help of indices like heat unit accumulation for a sustainable future. The correlation between the heat unit and other fruit characters needs to be studied in detail. Further, the mechanisms behind the process of accumulation of heat units and time duration in relation to mango maturity have to be studied deeper using the recent molecular and biochemical techniques.

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