

Existence of vivipary in mango (*Mangifera indica* cv. 'Amrapali') – A report

ABSTRACT

Aim: The Amrapali cultivar of mango is known for its dwarf stature, high productivity and ability to capture market late when mango from other regions of the country gets over. Vivipary is of unusual occurrence in mango. The aim of the study is to report occurrence of vivipary in mango especially in cultivar Amrapali under the sub-Himalayan subtropics of India.

Material and Methods: Incidental occurrence of vivipary in mango has been reported from Hamirpur district of Himachal Pradesh during the growing season of the year 2021. Upon observance of abnormal protuberances from the fruit surface, the harvesting was commenced at weekly interval and per cent proportion of viviparous fruits was ascertained by cutting the fruits longitudinally and confirming the viviparous germination of the seeds. Weather data of the fruit development state was analysed for accumulation of heat units and rainfall distribution and efforts have been made for ascertaining the reason behind the viviparous seed development in this cultivar.

Results and Discussion: The proportion of viviparous seeds increased with the progression of time and by the mid of September, more than 12% of seeds were found viviparous. The weather data show that there was early accumulation of heat units. Also, the rainfall during the period of fruit development was high particularly at the time when fruits were advancing toward maturity.

It has been observed that the seed maturity has preceded the fruit pulp maturity and ripening may be due the early accumulation of heat units and high rainfall; and this coincidence might have resulted in precocious germination of seed inside the fruit, leading to vivipary.

Conclusion: The development of vivipary in Amrapali mango has been found to be associated with the early accumulation of heat units and high rainfall. Under the current changing climatic scenario, a need has been projected for strategic research for curtailing vivipary incidences and saving economic losses to the growers of late mango varieties in the sub-Himalayan subtropics.

Keywords: Seed maturity, fruit maturity, ripening, heat units, rainfall, in-fruit germination

1. INTRODUCTION

The origin of mango (*Mangifera indica* L., Anacardiaceae) lies between the regions of North-Western Myanmar, Bangladesh and North-Eastern India. Wider adaptability enabled its cultivation in more than 65 tropical and subtropical countries across the globe. Worldwide, more than 56 million tonnes of mangoes were produced in 2019, of which 46% were produced in India (FAOSTAT, 2020). The mango is regarded as the 'King of Fruits' and has a cultivation area of more than 2.3 million hectares in this country (Statista, 2021). Over a hundred varieties of this crop are under cultivation and each has its own unique size, shape, sweetness, skin, and flesh colour. 'Alphonso', 'Amrapali', 'Benganpalli', 'Dashehari', 'Himsagar', 'Langra', 'Malda', 'Malgoa', 'Malika', 'Paiari', 'Zardalu' etc. are some of the popular cultivars of different mango growing regions of India.

The 'Amrapali' cultivar of mango was developed at the Indian Agricultural Research Institute, New Delhi by Dr. Pijush Kanti Majumdar as a hybrid of 'Dashehari' and 'Neelum' varieties. It is a cluster bearing variety known for its deep orange-yellow flesh colour and high β -carotene content (2.5 to 3.0 times higher than other commercial mango cultivars). Being regular in bearing, produces an average annual yield of 16 to 18 t/ha (Singh & Singh 2010; Ganeshamurthy *et al.* 2018). Since it is dwarf in stature, it is preferred for raising high-density orchards of mango under different agro-ecological situations in the tropical and subtropical regions of the country. The high-density orchards of this variety are also extending fast in the sub-Himalayan subtropics of North-west India where mango is grown mainly for capturing the late market. Under these geographic settings, the mango matures late when the crop is over from the other parts of the country. The 'Amrapali' cultivar develops attractive orange-yellow flesh colour and irresistible taste & flavour and is recommended for harvest during mid of August in this region (Sharma, 2011). Due to its late maturity, the availability of fresh mangoes in the market gets enhanced further by 10 to 15 days. The acreage therefore, is increasing fast under 'Amrapali' and other late-maturing varieties in the NW Indian conditions, especially in the sub-Himalayan subtropics.

Vivipary refers to the germination of seed inside the fruit without undergoing a period of rest. Goebel (1905) defined vivipary as the precocious and continuous growth of offspring when it is still attached to the maternal parent. In mango, vivipary is of an unusual occurrence. It is common in some mangrove species belonging to the Rhizophoraceae family, like, *Rhizophora mangle*, *R. mucronata*, *Bruguiera gymnorhiza*, *Kandelia candel*, *K. candel*, *Ceriops decandra* and many other members of this family which use this phenomenon as an adaptive mechanism in wetland ecosystem. It is often noticed in *Avicennia* sp., *Aegialitis rotundifolia*, *Aegiceras majus*, *Cocos nucifera*, *Cucumis melo*, *Sechiumedule*, *Oryzasativa*, *Triticumaestivum*, *Zea mays* etc. According to Stoutmeyer (1960), the vivipary is induced due to genetic mutation but, its manifestation can be modified by the environment. Reduced production or insensitivity of the fruit to abscisic acid has also been reported responsible for vivipary in many species (Hartmann *et al.* 2002).

The research on the vivipary of fruit crops attained little attention in the past as it is of rare occurrence in mango and other commercial fruit crops. Only numbered reports about its unusual occurrence in over-ripe 'Chausa' and 'Fazri' mangoes are available. There are no records available regarding the existence of vivipary in unripe mangoes especially those belonging to the cultivar 'Amrapali'. Moreover, it is an undesirable phenomenon for most horticultural crops as it reduces the marketability of the fruits.

2. MATERIAL AND METHODS

This incidental study on the 'Amrapali' cultivar of mango is based on the observations made in a home-scale garden in the Indian sub-Himalayan subtropics (31°40' 07" N, 76° 34' 46" E, 850 m a s l), in district Hamirpur of Himachal Pradesh. The trees under observation were growing under rainfed conditions without any external fertilizer or manure application; only the leaf litter of individual trees was incorporated into the basin of the individual trees, regularly. These trees were healthy and free from visual signs of any disease, nutrient deficiency or disorder. As usual, this year (2021) also, the phenological development of the cultivar 'Amrapali' proceeded normally with panicle initiation during mid-February and full bloom during the 3rd week of March. Every year, the fruits of this cultivar were being harvested during the mid of August, but, this year the harvesting was delayed due to the poor proportion of the fruits with harvest maturity. Therefore, from the 15th of August onwards, whatever number of fruits had matured (judged on the basis of initiation of redness in the yellow coloured pulp of randomly selected fruits amongst the fruits having full shoulder development) were harvested at weekly intervals. During the harvesting, there was observed a pin-headed protuberance at the surface of a few fruits. Such fruits were cut longitudinally for observing the nature of the protruding structure and to observe the stone suture for ascertaining the viviparous germination of the seed. For investigating the cause related to this unusual seed development, meteorological parameters of the current and past five years were studied, the data on temperature and rainfall variables of current and past five years were obtained from Accuweather and India Meteorological Department sites (Accuweather, 2021; IMD, 2021). From this data, the growing degree day's heat units (HU) were computed as per the procedure described by Oppenheimer (1947) and Halepotara *et al.* 2019. The state of maturity of seed leading to viviparous germination was assessed by comparing it with the *ex-situ* (away from parent plant) germinated seeds from the first harvest (15th August).

3. RESULTS

The data on the proportion of mango fruits harvested during different dates of harvest are presented in Table 1. It can be inferred from this data that every year the harvesting (about 97%) of the 'Amrapali' fruits was completed by the 15th of August in the past. During the current year, only a few fruits (7.89%) were found harvestable by this date. Out of the remaining fruits, 15.71 and 19.77 per cent fruits were harvested respectively on 30th August and 7th September. The rest of the fruits (56.63%), whether with harvestable maturity or not, were harvested on the 15th of September 2021.

During the harvest of 30th August, there was observed an unusual pin-head protuberance on the surface of a fruit. Such type of observation was never recorded during the harvest of previous years

(Table 2). The proportion of such fruits was initially low (less than 1%), but it was found to increase in the subsequent harvests. At the time of the second harvest, the proportion of fruits with pin-headed protuberance was observed to be 3.39%. It increased to 12.85% by the harvest of the 15th of September.

The pictures presented in Figure 1(a) shows the status of the mango crop as of the 15th September 2021 and figure 1(b) is showing the pin-headed protuberance. The longitudinal section of the fruit showing emergence of protuberance from seed is presented in figure 1(c). The extracted seed with split-open stone suture and subsequently emerged plumule of the germinated seed, confirming vivipary, are shown in figure 1(d). Figure 1(e) is presenting the germinated kernel separated from the stony endocarp of the fruit, the separated cotyledons and the attached plumule and radicle are clearly visible in figure 1(f). Figure 1(g) shows the stage of growth of the *ex-situ* germinated seed (the seed from the fruits of the first harvest). It reveals that both the seeds; one, which was inside the fruit and the other which was obtained from the fruits of the first harvest (15th of August), were almost of the same seed developmental or maturity state with respect to their readiness for germination as on 15th August. It can be presumed, therefore, that if the seed were extracted to be and sown for germination from the fruits which showed vivipary, might have attained the same growth level which the *ex-situ* germinated seed was showing.

The computed data for the cumulative sum of the growing degree day's heat units (HU) are presented in figure 2. It can be inferred from this figure that the cumulative sum of heat units is higher during the current year than the previous years' average. Moreover, the accumulation of heat units by the end of July is almost the same as it was up to August during the past five years. Further, the data on rainfall observed during the current year's fruit development and maturity period is presented in figure 3. The normal rainfall data for this period is also presented over here in this figure. The data reveals that this year the rainfall during the later fruit developmental stages (July) was comparatively much higher than the normal rainfall and this might have interfered with the processes of fruit maturity and ripening this year.

4. DISCUSSION

The seeded fruits possess necessary hormone (abscissic acid) to suppress the germination of seed until it is extracted out from the fruit (Fransworth and Farrant, 1998). Abscissic acid plays a pivotal role in the reproductive biology of mangrove species as they experience extensive extent of viviparous germination due to the lower influence of this germination suppressing hormone. The crops like tomato have been reported to possess enzymes like methyltransferase1 and over ripening as stimulants which modulates vivipary during fruit development (Mengqin *et al.* 2020). This phenomenon has been observed frequent in other fruit crops like strawberries, peppers, pears, citrus fruits etc. but, mango was believed to be free from viviparous seed. Most of its commercial cultivars take around 14 to 20 days for germination and result in 50 to 55% germination (Kumari *et al.* 2019). But, a few available reports described the existence of vivipary in this fruit crop, also. Singh and Ram

(1999) reported vivipary in late-maturing 'Fazari' cultivar and attributed it to paclobutrazol and higher N application. However, they described 'Dashehari', and 'Langra' varieties as free from viviparous seed development. High N application as a reason for viviparous seed development in 'Chausa' mango was also reported by Tipu (2019). But, in the present studies, the 'Amrapali' plants were given neither N nor paclobutrazol application but still, viviparous development of seed was observed; it implies that for vivipary to occur the stimulus of high N or paclobutrazol application may not be essential. Tipu (2019) further reported the early accumulation of heat units as another cause of viviparous seed development. As per present studies, this reason seems to hold good because not only the total accumulation of heat units was higher during the current growing season but the sum total of the heat units which accumulated by the end of July was almost equivalent to the heat units which accumulated up to August during the previous years (figure 2). It means the early accumulation of heat units certainly has a relation with the viviparous seed development in the 'Amrapali' mango also. But, the observations gave rise to a question that if the early accumulation of heat units has accelerated the process of seed development and maturity leading to precocious seed germination inside the fruit, why a similar effect was not observed for fruit maturity which was otherwise late during this year. Normally, fruit and seed development goes hand-in-hand but in the present observations why has the maturity of fruit lagged behind that of seed? The answer to this question was tried to be traced out from the rainfall data. From this data, it can be observed that there was high rainfall during the month of July (38.4% higher than normal). An ambivalent correlation of high humidity with vivipary has also been reported by Allard (1999) and Doggett (1976) in grasses and some other plant species.

In the present studies, the coincidence of completion of heat unit requirement with high rainfall might have favoured the germination of seed inside the fruit. Contrarily, the process of fruit maturity was decelerated due to prevailing raining and this might have resulted in the differentiation in the timings of pulp and seed maturity. The importance of excess rain-free, hot and dry weather in mango fruit development was also emphasized by Rajan (2012) and Khanna (2018). Therefore, it can be speculated that the influence of the environmental factors is more pronounced on fruit pulp maturity and ripening, the development of seed keeps on proceeding as per its genetic or hormonal constitution, with the lesser direct influence of environment on its growth and development. It can be said that in the case of 'Amrapali' mango viviparous seed development is a case of seed maturity precedence over the fruit maturity due to early heat unit accumulation together with high rainfall hampering fruit maturity. The report of Singh and Chauhan (2013) that vivipary is the resultant of high humidity during ripening of 'Chausa' mango is of ambivalent support for the present findings as ripening was not noticed essentially for vivipary to occur in the present studies. In a nutshell, it can be stated that under the present studies, the early accumulation of heat units has favoured the precocious development of 'Amrapali' seeds. High rainfall, on the other hand, retarded fruit maturity creating a pace gap between fruit and seed maturity. As the general nature of mango seed is recalcitrant, doesn't require any period of rest for its germination (Roberts, 1973 and Singh & Tawil, 1968); upon attaining maturity, it perceived (mimicked) maturing fruit pulp as rooting media and gave birth to the next generation *i.e.* precocious viviparous seed development has occurred.

5. CONCLUSION

In fruit crops vivipary has received little attention despite the fact that it is of tremendous importance for fruit quality traits, breeding, the evolution of seed dispersal mechanism etc. The present studies concluded that the occurrence of vivipary is not uncommon in mango. Though germination of seeds, whether recalcitrant or orthodox, is more of a hormonal or genetic phenomenon; the environmental stimulus like early accumulation of heat units and high rainfall just after the completion of required heat units, induced a pace change in fruit maturity and/or seed maturity. Being recalcitrant, as soon as its maturity was completed, the seeds mimicked maturing fruit pulp as rooting media and gave birth to new offspring i.e. viviparous development of the seed. It is also concluded from the studies that the development of fruit and seed are separate phenomena, seed maturity may precede fruit maturity resulting in vivipary. As the climate is there and it is going to stay long, therefore the variability of meteorological parameters is expected to increase and thereby the incidences of viviparous seed development may also increase in near future. Therefore, the orchardists who have planned or are planning for capturing the late market of mango through 'Amrapali' cultivation are required to give due attention toward early heat accumulation, rainfall and other meteorological parameters prevailing in their agro-climatic situation. As this eco-physiological disorder can have stronger economic implications, it is imperative to have strategic research attention for working appropriate remedial measures for the prevention of vivipary in fruit crops.

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Table 1. Proportion (%) of fruits harvested on different dates

Year	Date of Harvest			
	15th August	30 August	7 th Sept.	15 th Sept.
Avg. 2016-20	97	3	-	-
2021-10-27	7.89	15.71	19.77	56.63

Table 2. Observed proportion (%) of fruits with an unusual protuberance as on 30st August onwards

Year	Date of observation		
	30 th August	7 th September	15 th September
Avg. 2016-20	Nil	Nil	Nil
2021-10-27	0.95	3.39	12,85

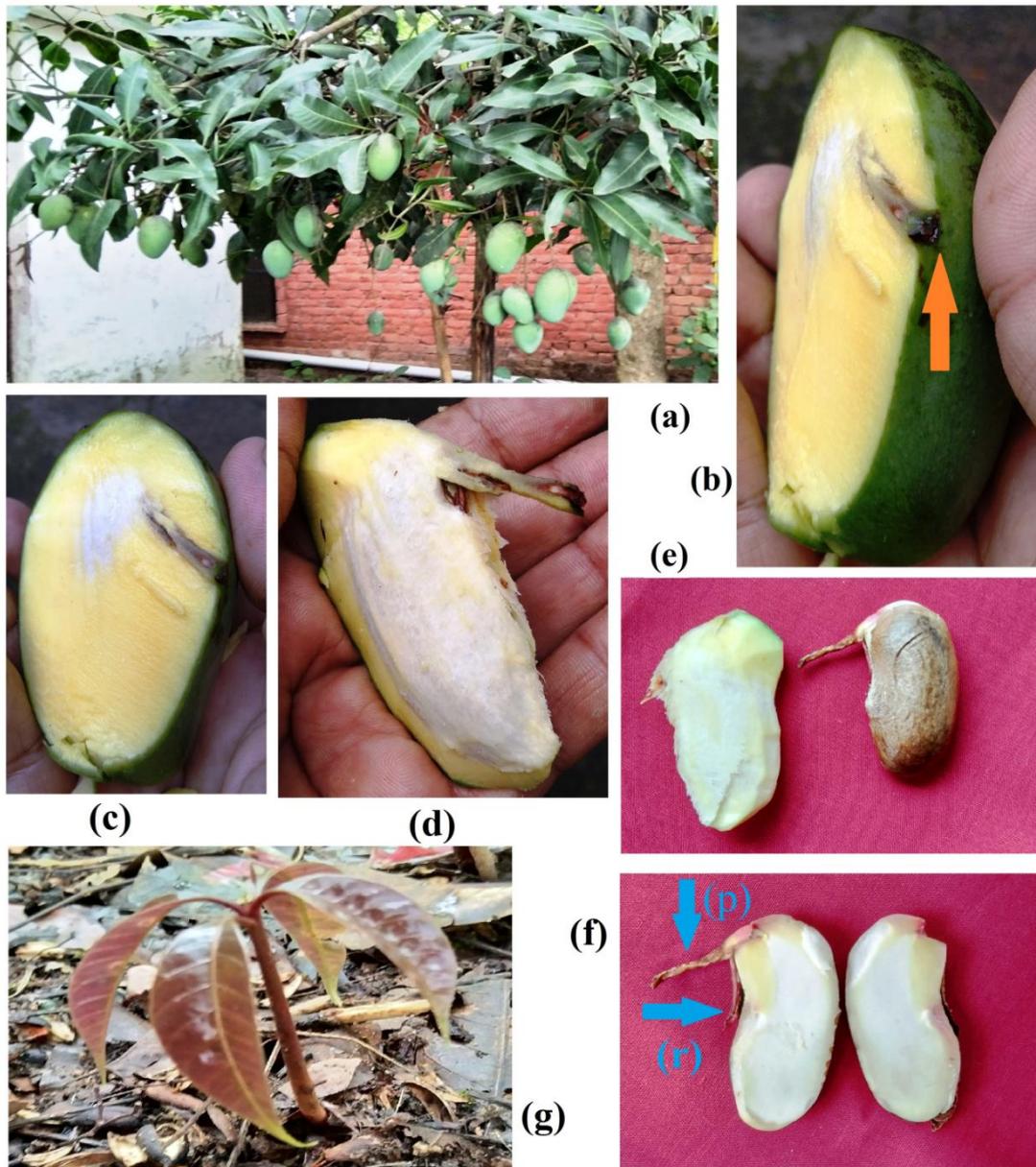


Figure 1. Mango ‘Amrapali’ vivipary: (a) bearing status of ‘Amrapali’ on 15 Sept 2021; (b) protruding structure (plumule) visible at fruit surface; (c) LS of fruit showing vivipary; (d) viviparous seed; (e) separated stone and kernel of viviparous seed; (f) cotyledons showing the radicle (r) and the plumule (p); (g) *ex-situ* germinated seed of mango.

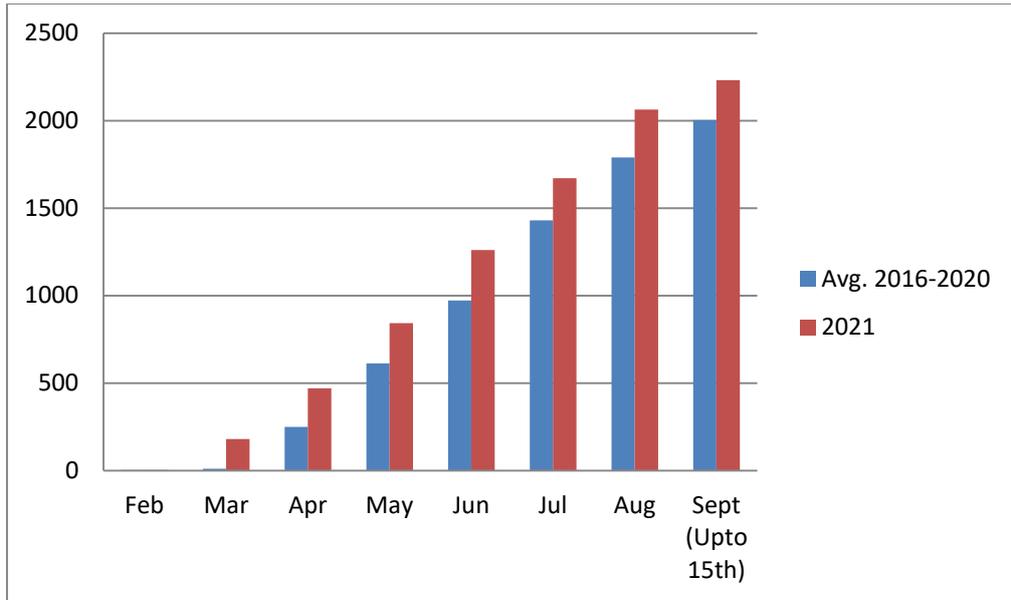


Figure 2. Cumulative growing degree days heat units (HU) February 1 to September 15

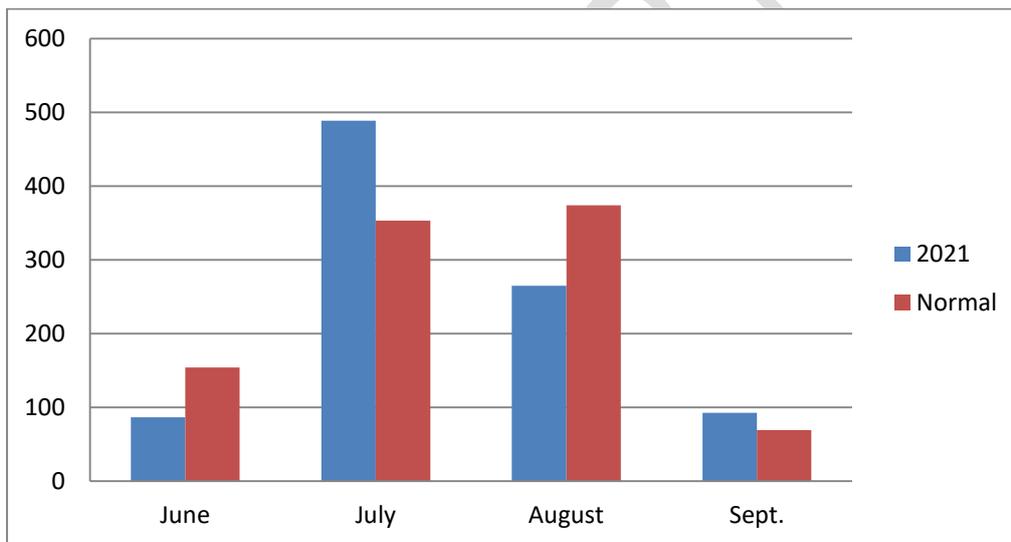


Figure 3. Rainfall (mm) received during later fruit development stages