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Effect of heat unit and time duration required for maturation of mango (*Mangifera indica* L.) CV. Kesar.

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Abstract
An investigation entitled "Effect of heat unit and time duration required for maturation of mango (*Mangifera indica* L.) cv. Kesar." was undertaken with an objective to evaluate different maturity stages of Kesar mango for physical and quality characters. The study was carried out at Fruit Research Station, Lal Baug, Department of Horticulture, College of Agriculture, Junagadh Agricultural University, Junagadh, during the year 2016. The experiment was laid out in RBD with eight stages of mango maturity *viz.*, 85 days, 90 days, 95 days, 100 days, 105 days, 110 days, 115 days, 120 days (after fruit set) with three replications. The mango fruits harvested from trees were selected for the study and in each tree, 100 fruits were labelled at fruit set of above mentioned days. From the results of the present investigation, it's revealed that among the different time period taken for maturity significantly influenced the physical parameters, quality parameter, time taken to maturity, marketable fruits and spoilage of fruits in mango cv. Kesar. Mango fruits harvested at 105 days of fruit set (T_5) with accumulation of 1020 HU was found to be the best. Fruits harvested at 105 days reported better physical characteristics and quality parameters like TSS, minimum acidity, sugars, carotenoid content, and more marketable fruits with minimum spoilage which are more acceptable in the market.

Keywords: Heat unit (HU), mango, Kesar, maturity days, maturity indices, quality

Introduction
Mango (*Mangifera indica* L.) unarguably is one of the oldest and choicest tropical fruit of the world and is rightly designated as "King" of all fruits. Mango belongs to family Anacardiaceae, which is originated in Indo-Burma at an early date. Historical records suggest that its cultivation as a fruit tree originated in India around 4000 years ago. Due to its wide adaptability, high nutritive value, richness in variety, luscious taste, captivating flavour and attractive appearance it enjoys the unique popularity among the masses and classes. Because of its naturally built in qualities, mango is now gradually gaining global market and occupies the same position as apple gets in temperate countries and grape in certain regions (Sikhamany, 2005) [32]. Around 2000 varieties of mangoes are found in the world. Out of them, majority of varieties are cultivated in India. India produces around 19.68 million metric tonne of mangoes every year from 2.26 million ha area (Anon., 2017) [2]. Gujarat itself produces 13 lakh tons of mango which contributes around 7 per cent in the total lot. Especially in Junagadh district total of 84120 tonne mango produce from 21030 ha area (Anon., 2017) [2]. Mango is the leading fruit crop of Gujarat and Saurashtra region. Kesar is the most important commercial variety not only for this region, but emerging as one of the leading variety of Gujarat. Kesar is a chance selection from *"Salebhai ni Amadi"* the indigenous variety. Kesar is the only variety which is grown under systematic orchards in Saurashtra region. It posses pleasant characteristics like saffron coloured pulp, sweet taste, fiberless pulp, small & flat stone, yellow coloured fruit, etc. For fetching higher price in the market, production of high quality produce is of utmost importance. Apart from orchard management, cultural practices, post harvest treatments and proper time of harvesting plays an important role for quality production and planning for commercial marketing. Harvesting at the optimum stage of maturity reduces the different kinds of pre and post harvest losses. Being a climacteric fruit, the mango fruits have to be harvested at physiological maturity, much before ripening. For attaining desirable quality after ripening, harvesting at proper maturity stage is of utmost importance. Different criteria are being used for determining the stage of maturity in mango fruits. *Tapka* (falling of fruits from the tree), proper development of shoulder, specific gravity, skin colour are some of the criteria used for deciding the harvesting time in mango. However, computational method using heat unit accumulation during the fruit growth and development has been used as an easy and feasible criterion for determining the fruit maturity.

A Heat unit is defined as a mean daily temperature one degree above (base) temperature.

HU = Mean Daily Temperature - Certain (Base) Temperature.

Calculation

HU are calculated by measuring accumulated heat within 24 hrs. HU are calculated by taking the average of the daily maximum and minimum temperatures compared to a base temperature, T base (usually 10 °C). For mango 17.9 °C is Base Temperature.

$$HU = \frac{Tmax + Tmin}{2} - Tbase$$

Heat Unit accumulation can minimize such deviation and proper stage of maturity can be achieved. Even in case when less number of HU or more numbers of HU are accumulated in the fruit it has its individual effect on fruit physical, chemical parameters and sensory evaluations too.

Materials and Methods

The study was undertaken at Fruit Research Station, Lal Baug, Department of Horticulture, College of Agriculture, Junagadh Agricultural University, Junagadh during 2016. During the investigation physical characteristics of mango fruit were evaluate immediately after harvest stage. Calculated heat units received from fruit set to maturity of mango fruits. The experimental material, *i.e.* Kesar mango fruits were obtained from the orchard of Department of Horticulture College of Agriculture, JAU, Junagadh, Gujarat India. Junagadh is situated in South Saurashtra Agro Climatic Region of Gujarat state and enjoys a typically subtropical climate. Fifteen uniform mango tree of Kesar were selected for the study and on each tree 100 fruits were labeled at 70 per cent fruit set stage. The tagged fruits of uniform size were harvested for conducting the experiment during the year 2016. They were harvested at eight stages (85, 90, 95, 100 105, 110, 115 and 120 days). The experiment was laid out in RBD with three replication and eight treatment, *viz.* T1 (Mango fruit harvested at85 days after fruit set), T2 (Mango fruit harvested at 90 days after fruit set), T3 (Mango fruit harvested at 95 days after fruit set), T4 (Mango fruit harvested at 100 days after fruit set), T5 (Mango fruit harvested at 105 days after fruit set) T6 (Mango fruit harvested at 110 days after fruit set) T7 (Mango fruit harvested at 115 days after fruit set) T8 (Mango fruit harvested at 120 days after fruit set). The observations were recorded and when they immediately after harvest stage. For studying physical parameters ten fruits were randomly selected and observations were recorded on the physical characteristics *i.e.*, fruit weight, volume, specific gravity, length, breadth, pulp weight, peel weight, stone weight, stone length, stone breadth. Peel colour was measured at the equator on opposite cheeks of the fruit. Pulp colour was measured in the center of one cut cheek, with two measurements per fruit. The firmness of the fruit was tested by means of a pocket penetrometer (Italy made, fruit tester, model FT-327). The statistical analysis was done according to the techniques given by Panse and Sukhatme (1985) [24] using Randomized Block Design and valid conclusion were drawn only on significant differences between treatment mean at 0.05% level of significance.

Results and Discussion

Effect on physical parameters

Data pertaining to physical characteristics, *viz.* weight, volume, length, breadth, weight of pulp, weight of peel, weight of stone, length and breadth of stone of mango fruits during different maturity stages are presented in tables 2. It is revealed from the data that most of the physical parameters showed variation due to different maturity stages of mango. The data showed that volume of fruit was increased with delayed harvesting. The maximum volume of fruit (187.50, 212.67 cm^3) at the time of harvesting as well as ripening time, respectively was recorded in fruits harvested at 120 days after fruit set (T_8). It might be due to the fact that fruits attached maximum numbers of days (120 days after fruit set with HU-1271) to its mother plant Hence, received more nourishment from mother plant. Wang and Shiesh (1990) [37] reported that most of the volume of the fruit was achieved during 75-80 days and thereafter there was a slow increase in fruit volume, although the fruit attained maximum volume at 90 days after fruit set, when it had out grown shoulders and depressed stem. Increase in fruit volume was noted up to last picking. Similar findings have also been obtained by Palaniswamy *et al.* (1974) [22], Garg *et al.* (1975) [9] and Dianlong (2013) [7]. The maximum breadth of fruit (6.29 cm) was recorded in fruits harvested at 120 days after fruit set (T_8), which was at par with T_3, T_4, T_5, T_6 and T_7. The accretion of HU generated significant effect on the HU requirements for the breadth of fruit. The accumulation of extra HU (1271 at 120 days after fruit set) might accelerate the physiological processes in the fruit. These findings are also supported with results of Mollah and Siddique (1973) [18], Badiyala and Awasthi (1990) [3]. The highest weight of fruit was recorded in fruits harvested at 120 days after fruit set (T_8) with value of 175 (g). Increases in fruit weight between successive harvest dates can be expected as the fruits require more time for the accumulations of HU, photosynthates, nutrients, water, etc., which are primarily responsible for increase in fruit weight. These extra accumulations of HU (1271 with daily HU- 10.59) might have boosted the cell division and increase in physiological activities. Similar findings have also been obtained by Roy *et al.* (1972) [27], Palaniswamy (1974) [23], Gole (1986) [11], Shrivastava *et al.* (1987) [30]. The minimum stone length (5.80 cm) and stone breadth (2.42 cm) was found in fruits harvested at 85 days after fruit set (T_1). The growth of stone in terms of breadth and length was rapid during early stage of growth from fruit set but thereafter a gradual increase in stone was observed. Due to climatic condition especially temperature, the accumulation of HU will vary at different maturity periods which is directly related to the physiological processes in the fruit. Fruits attached with mother plant received more nourishment with extra accumulation of HU. The accumulated HU, daily HU and periodical HU (1271, 10.59, 0.21), respectively were noted in fruits harvested at 120 days after fruit set as compared to early (85 days) harvested fruits. It is supported with results of Sadhu and Bose (1976) [28], Naik (1985) [20], Ghosh *et al.* (1985) [10], Gole (1986) [11], Shafique *et al.* (2006) [29], Lechaudel and Joas (2006) [14] and Lucena *et al.* (2007) [15]. Effect of period of harvesting and accumulated heat unit on weight of stone and peel were found non significant. It is observed that the pulp: stone ratio (3.67) of fruit was higher in fruits harvested at 120 days after fruit set (T_8) whereas, pulp: stone ratio (2.45) was lower in fruits harvested at 85 days after fruit set (T_1). It might be due to reduction in thickness of skin thus contributing more pulp to the total fruit weight. It might be due to the fact that during the last phase of fruit growth the Mesocarp tissue still increases in size and weight. Whereas, the endocarp tissue experiences arrested growth as it has already attained

maximum size and weight by then. These findings are in close conformity with the results of Shyamal and Mishra (1987) [31] and Kanzaria (2015) [12].

The maximum days (14 days) taken to ripening were recorded when fruits harvested on 85 days after fruit set (T_1), which was at par with T_2, T_3, T_4, and T_5 (13.50, 13, 12, 11 days). Whereas, fruits harvested on 120 days after fruits set ripen early (2.50 days). A day taken to ripening of fruit was decreased with the increase in maturity period. It might be due to the fact that in early harvested fruits the ethylene production might not reached up to the mark and immature tissues losses moisture and start shrivelling as the storage period increased. Whereas fruits which were harvested late undergoes early ripening, as mango is climacteric fruit. They cannot be stored for longer period. These results are in close proximity with the earlier findings of Emmanuel *et al*. (2009) [8] and Tridjaja and Mahendra (2000) [36] in mango.

Effect on Chemical parameters

It is opined from Table 4.3 that the significant differences were noted in TSS of mango fruits due to different maturity days and accumulated heat unit. Early harvested mango fruits had less TSS as compared to late harvested fruits it might be due to inadequate hydrolysis of starch into simple sugars. Another probable reason might be extra accumulation of HU in late (120 days) harvested fruits which is 1271 as compared to early (85 days) harvested fruits, which increase physiological activities in fruits. Emmanuel *et al.* (2009) [8], Dang *et al.* (2008) [6], Lebrun *et al.* (2008) [13], Tridjaja and Mahendra (2000) [36]. The titrable acidity of fruits gradually decreased with the progress of days towards harvest in all the treatments. The titrable acidity percentage (0.97, 0.20 %) was lower in fruits harvested at 120 days after fruit set (T_8) at the time of harvesting as well as ripening time, respectively. The late harvested fruits recorded lowest acidity throughout their storage which may be due to optimum ripening process in the fruits as compared to early harvested fruits as they attached with mother plant for longer and get more nourishment due to accumulation of HU (1271), photosynthates and physiological activities increases. Similar results were also earlier reported by Abourayya *et al.* (2011) [1], Emmanuel *et al.* (2009) [8], Dang *et al*. (2008) [6], Lebrun *et al.* (2008) [13]. Among the maturity stages, higher level of reducing sugar (1.34, 6.15 %) was registered in fruits harvested at 120 days after fruit set (T_8) at the time of harvesting as well as ripening respectively. Slow ripening process in early harvested fruits resulting in slow hydrolysis of starch which liberating reducing sugar slowly, ultimately lower content of reducing sugar was recorded in treatment (T_1). On the other hand late harvested fruits showed more hydrolysis of starch at faster rate due to more daily HU (10.59) which increased reducing sugar. These results are in close proximity with the earlier findings of Teaotia *et al.* (1967) [35] in mango, Moti and Gangwar (1973) [19], Patel (2013) [25], Zagade and Relkar (2014) [38] and Kanzaria (2015) [12].

The total sugar content (5.60, 17.22 %) was higher in fruits harvested at 120 days after fruit set (T_8) at the time of harvesting and ripening, respectively. The total sugars were lower in earlier harvested fruits but due to shrivelling of fruits these treatments were not marketable. The accumulated HU, daily HU, and periodical addition of HU (1271, 10.59, 0.21), respectively might be responsible for increasing physiological activities in late (120 days) harvested fruits. Accumulating a sufficient amount of starch would allow the ripe fruit to be able to synthesize large amount of sugar at optimum maturity stage. This is supported by significant activities of starch breakdown and sugar synthesis enzymes in late harvested fruits. These results are in line with Moti and Gangwar (1973) [19], Patil (1990) [26], Kanzaria (2015) [12]. The ascorbic acid content was decreased with the advancement of ripening process (Table 3). The early harvested fruits delayed ripening due to slow ripening changes and metabolic activities. So it retains higher ascorbic acid content as compare to rest treatments. These results are analogous with the earlier findings of Abourayya *et al.* (2011) [1], Dang *et al.* (2008) [6] and Moti and Gangwar (1973) [19] in mango. There was a gradual increase in the total carotenoid content of mango fruits with advancement in picking maturity as well as during ripening. Advancement of heat unit at 120 days after fruit set which is 1271 might be responsible for increasing physiological activities in fruits. These results are in close proximity with the earlier findings of Tandon and Kalra (1983) [34] and Chaudhary (2006) [5].

Organoleptic parameters

The fruits that were harvested on earlier sampling dates (85 days) did not develop proper colour and other quality attributes on ripening as immature tissue losses water and showed signs of shrivelling after a 7 day ripening period due to less accumulation of HU (694) and also not get proper nourishment from mother plant as harvested early.. Pulp colour was lower in early stage of growth from fruit set but thereafter a gradual increase was observed. Medlicott *et al.* (1986) [17] concluded that mango fruit pulp contained high concentrations of carotenoids, causing the development of an intense yellow to orange colour on ripening. texture was lower in early stage of growth from fruit set but thereafter a gradual increase was observed. It might be due to the fact that early harvested fruits not ripen properly, immature tissues losses water, start shrivelling as storage period advanced and texture is loss. This findings are in close conformity with the results of Man *et al.* (1974) [16], Singh *et al.* (1976) [33], Tandon and Kalra (1983) [34], Banik and Sen (2003) [4], Obasi (2004) [21]. The scores for overall acceptability rating showed an increase trend during ripening of those fruits that were harvested upto 110 days after fruit set in comparison to their initial values in all the treatment, whereas fruits harvest from 115 days after fruit set showed a decline in overall acceptability rating during ripening. Such an effect can be expected as fruits harvested early or late contained lower TSS, and sugar contents in comparison to fruit harvested at optimum maturity thereby making them less acceptable. Fruits harvested early may have failed to ripen properly and contained lesser quantities of sugars than those harvested at the pre climacteric stage and ripened (Zauberman, 1975) [39].

Table 1: Heat units received from fruit set to reach the different stages of maturity in mango cv. Kesar fruits.

Treatment details	Accumulated HU	Daily HU	Periodical addition of HU
T_1-85 days after fruit set	694	8.16	--
T_2- 90 days after fruit set	772	8.57	0.41
T_3 -95 days after fruit set	859	9.04	0.47
T_4 -100 days after fruit set	935	9.35	0.31

T_5-105 days after fruit set	1020	9.71	0.36
T_6-110 days after fruit set	1112	10.10	0.39
T_7-115 days after fruit set	1194	10.38	0.28
T_8-120 days after fruit set	1271	10.59	0.21

Table 2: Effect of heat unit and time duration on physical parameters of fruits in mango cv. Kesar.

Treatment	Volume of fruits (cm^3)		Length of fruit (cm)	Breadth of fruit (cm)	Weight of fruit (g)	Length of stone (cm)	Breadth of stone (cm)	Weight of stone (g)	Weight of pulp (g)	Weight of peel (g)	Pulp: Stone ratio	Days taken to ripening
	Harvesting	Ripening										
T_1	81.50	139.17	8.13	5.18	121.10	5.80	2.42	28.00	68.00	22.67	2.45	14.00
T_2	116.43	145.00	8.66	5.33	139.83	7.18	2.60	28.50	81.67	22.50	2.91	13.50
T_3	130.00	166.67	8.79	5.83	144.30	7.42	3.13	29.00	84.83	20.17	2.93	13.00
T_4	141.67	173.33	9.01	5.78	159.63	7.55	3.13	29.67	98.83	19.83	3.34	12.00
T_5	168.33	185.83	9.03	6.20	167.10	7.62	3.15	30.00	109.17	18.33	3.64	11.00
T_6	174.17	205.00	9.31	6.26	169.67	7.67	3.18	30.17	109.83	18.00	3.65	8.00
T_7	178.67	209.33	9.33	6.28	172.27	7.72	3.21	30.18	110.00	16.67	3.65	4.00
T_8	187.50	212.67	9.35	6.29	175.00	7.75	3.22	30.29	110.67	16.33	3.67	2.50
S. Em.±	8.288	13.993	0.403	0.231	5.973	0.358	0.184	1.285	3.600	1.471	0.183	1.238
C.D. at 5%	25.14	42.44	NS	0.70	18.12	1.09	0.56	NS	10.92	NS	0.56	3.76
C.V. %	9.75	13.49	7.81	6.79	6.63	8.46	10.58	7.55	6.45	13.20	9.67	22.00

Table 3: Effect of heat unit and time duration on chemical parameters of fruits in mango cv. Kesar.

Treatment	TSS (°B)		Acidity (%)		Reducing sugar (%)		Total sugar (%)		Ascorbic acid (mg/100g)		Carotenoid content (µg/100g)	
	Harvesting	Ripening	Harvesting	Ripening	Harvesting	Ripening	Harvesting	Ripening	Harvesting	Ripening	Harvesting	Ripening
T_1	7.58	11.53	4.55	1.01	1.13	4.75	5.16	14.97	20.09	13.87	69.67	308.67
T_2	8.40	12.43	4.27	0.93	1.21	4.95	5.25	15.50	20.08	13.79	159.83	370.00
T_3	8.47	13.79	2.73	0.79	1.27	5.21	5.37	15.73	20.08	13.73	281.00	372.33
T_4	8.88	14.40	2.70	0.65	1.29	5.47	5.46	15.94	19.98	12.92	282.33	399.00
T_5	9.17	14.70	2.55	0.56	1.30	5.56	5.54	15.99	19.84	12.77	290.00	456.33
T_6	9.25	17.00	1.25	0.45	1.32	5.76	5.60	16.30	19.77	12.80	296.00	460.33
T_7	9.37	17.85	1.09	0.23	1.33	6.01	5.60	16.69	18.89	12.02	321.33	468.67
T_8	9.67	18.17	0.97	0.20	1.34	6.15	5.60	17.22	18.72	11.15	328.00	477.67
S. Em.±	0.402	0.796	0.174	0.070	0.042	0.295	0.093	0.421	0.334	0.570	16.500	28.279
C.D. at 5%	1.22	2.42	0.53	0.21	0.13	0.89	0.28	1.28	1.01	1.73	50.05	85.77
C.V. %	7.88	9.20	11.95	20.23	5.73	9.32	2.94	4.54	2.94	7.66	11.27	11.83

Table 4: Effect of heat unit and time duration on organoleptic parameters of fruits in mango cv. Kesar.

Treatment details	Peel colour	Pulp colour	Texture	Taste	Flavour	Over all accept ability
T_1-85 days after fruit set	3.73	4.42	4.23	2.91	3.23	3.71
T_2- 90 days after fruit set	4.18	5.02	4.55	4.65	4.14	4.50
T_3 -95 days after fruit set	5.38	5.39	4.82	4.38	4.83	4.96
T_4 -100 days after fruit set	6.28	5.72	5.21	5.44	5.22	5.57
T_5-105 days after fruit set	7.20	7.95	5.44	7.61	5.71	6.78
T_6-110 days after fruit set	8.08	8.21	6.98	7.85	7.61	7.75
T_7-115 days after fruit set	7.72	8.19	6.35	7.83	6.96	7.29
T_8-120 days after fruit set	7.43	8.00	5.51	7.05	6.80	6.96
S. Em.±	0.485	0.548	0.409	0.314	0.442	0.214
C.D. at 5 %	1.47	1.66	1.24	0.95	1.34	0.65
C.V. %	13.43	14.37	13.15	9.11	13.75	6.25

Conclusion

Mango fruits harvested at 105 days of fruit set (T_5) with accumulation of 1020 HU was found to be the best. Fruits harvested at 105 days reported better physical characteristics and quality parameters like TSS, minimum acidity, sugars, carotenoid content, more marketable fruits with minimum spoilage which are more acceptable in the market. Hence, for optimum physical and quality parameters and maximum marketable fruits of mango cv. Kesar should be harvested at 105 days after fruit set (HU 1020).

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