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Prediction of mango fruit maturity using growing degree days

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Abstract
The experiment was under taken at Fruit Research Station, Sakkarbaug, Junagadh Agricultural University, Junagadh which falls under South Saurashtra Agro-climatic conditions. The experiment was carried out for consecutive four years from 2013-14 to 2016-17 to estimate the effect of accumulation of growing degree days on flowering, maturity and yield of various mango varieties. Four commercial varieties *viz*, Kesar, Alphonso, Jamadar and Dudhpendo were selected for the study with Randomized Block Design and five replications. An early bud differentiation was noted with minimum days for BDS (165.75 days with 1511.02 GDD in Jamadar), early flowering (84.73 days with 390.73 GDD) and fruit set (21.76 days with 125.38 GDD) in Alphonso was calculated. While early pea stage (21.63 days with 124.08 GDD), marble stage (40.95 days with 371.44 GDD) and maturity (97.65 days with 1123.83 GDD) was observed in Kesar variety. The highest fruit set at pea stage (14.41%) and marble (1.59%) was noted in Jamadar variety and maximum fruit weight (247.36 g in Jamadar) and maximum pulp weight (174.84 g), fruit length (10.77 cm), fruit width (6.81 cm) was reported in Kesar. Though, minimum peel weight (27.18g), stone weight (18.18 g) and more number of fruits per plant (359.75) was reported in Dudhpendo. The maximum yield per plant (74.72 kg), yield tons per ha. (7.54) and highest HUE (6.75 kg/ha/^{o}day) was observed in Kesar. The highest HTU (13155.72 ^{o}day hrs) and PTU (26613.46 ^{o}day hrs) during BDS and similarly at maturity (11942.33 ^{o}day hrs) and PTU (12182.69 ^{o}day hrs) were reported in Kesar. But for flowering and fruit set the highest HTU (7471.90 and 1111.24 ^{o}day hrs) and PTU (9973.37 and 139.14 ^{o}day hrs), respectively were recorded for Dudhpenpdo. Thus, GDD have direct influence on flowering to fruit maturity. A mango variety Kesar requires low GDD for maturity with higher Heat Use Efficiency and Photo Thermal Unit.

Keywords: Flowering, fruit set, GDD, mango, variety, HUE, HTU, PTU

Introduction
The idea of growing degree days (GDD) was introduced almost 300 years ago, in 1730, by the French scientist Rene A. F. de Reaumur. Since that time, GDD has been used as a means to predict the growth stages of many living organisms. Growing Degree Days (GDD) is the number of temperature degrees above a certain threshold base temperature within consecutive 24 hrs period. The GDD varies among crop or even within cultivars of the same crop. So, GDD= Mean Daily Temperature- Certain (Base) Temperature (usually 10 °C; for mango 17.9 ^{o}C). Climate change is already having an effect on farming, thereby increasing the need for research and programs to assist adaptive decision making (Byrne *et al.* 1992, Majumder *et al.* 1990) [2, 12]. Patterns of temperature, moisture and weather conditions greatly influence plant and animal performance, inputs, management practices, yields, and economic returns. In general, recommendations are made on the basis of date/ calendar days. Selection of suitable crops and cultivars on the basis of GDD is possible for the area. Temperature, humidity and bright sunshine hours are the most important factors affecting plant life after soil, moisture and nutrients (Mathieu 2006, Farheen *et al.* 2017a) [14, 5]. The experiment was under taken to estimate the effect of temperature on different varieties of mango under South Saurashtra Agro-climatic conditions with objective to estimate requirement of Growing Degree Days (GDD) accumulation on flowering, fruit maturity and yield of different mango varieties under South Saurashtra Agro-climatic conditions.

Result
The experiment was carried out at Fruit Research Station, Sakkar baug farm, Department of Horticulture, JAU, Junagadh in RBD design with five replications from the year 2013 to 2016.

Four popular mango varieties in region *viz.* V_1 (Kesar), V_2 (Alphonso), V_3 (Jamadar) and V_4 (Dudhpenda). The Cutoff date for GDD calculation was 1st, July. Base Temperature for mango was taken 17.9ºC. The significant differences for the days required for the BDS were not found for all individual years. Though, it was found significant in pooled data and early bud differentiation was noted with minimum days for the BDS in variety Jamadar (165.75 days with 1511.02 GDD) and it was found at par all the varieties except V_4. The differences for the days required for the flowering and fruit set among four mango varieties was found significant for individual year as well as pooled data. Early flowering with minimum days was observed in Jamadar (80.40 days with 360.89 GDD and 87.80 days with 391.00 GDD) and in Alphonso variety (87.40 days with 397.70 GDD; 78.50 days with 390.40 GDD and 84.73 days with 390.23 GDD) for the all the years and pooled, respectively and found at par with two other varieties except V_4. Significantly the maximum days for the flowering were taken by V_4 and bear late for all the year and pooled. Early fruits set with minimum days was observed in Jamadar (20.40 days with 116.52 GDD and 21.20 days with 82.30 GDD) and in Alphonso variety (21.00 days with 136.20 GDD; 19.85 days with 126.80 GDD and 21.76 days with 125.38 GDD), for all the years and pooled, respectively and found at par with two other varieties except V_4. Days required for attaining pea, marble stage and maturity were found significantly differed among all the varieties. Minimum days for pea stage were required by variety Jamadar (20.00 days with 138.80 GDD, 21.00 days with 138.80 GDD) and in Alphonso (20.50 days with 165.20 GDD, 21.80 days with 155.00 GDD) for individual year, respectively. As far as pooled data are concerned mango variety Kesar reported the least days (21.63 and 124.08 GDD) for pea stage and was at par with V_2 and V_3. For the year 2013 V_3 was found at par with V_1 and for the year 2014 it was at par with V_1 and V_2 (Table-5). Significantly minimum days for marble stage (36.00 and 346.54 GDD and 40.40 days with 317.60 GDD) for the year 2013 and 2014 were reported in Jamadar, respectively. Kesar required minimum days (39.90 with 351.20 GDD, 39.70 days with 383.60 GDD and 40.95 days with 371.44 GDD) for year 2015, 2016 and pooled, respectively (Farheen *et al.* 2017b, Kanzaria *et al.* 2015b and 2015c) [6, 10, 11].

The early maturity was found in mango variety Jamadar (86.20 days with 1052.40 GDD and 98.60 days with 1075.60 GDD) for the year 2013 and 2014, respectively and found at par with Kesar. Variety Kesar recorded early maturity of fruits and reported least days (98.40 days with 1051.60 GDD, 99.00 days with 1193.40 GDD and 97.65 days with 1123.83 GDD) for the year 2015, 2016 and pooled, respectively. Kesar required minimum GDD for the maturity. The significant results were found for fruit set at pea and marble stage in mango varieties. For the year 2013 fruit set was found non-significant. Jamadar reported the maximum fruit set (13.98, 15.48, 13.96 and 14.41%) for the year 2014, 2015, 2016 and pooled, respectively. The maximum fruits at marble stage (1.69, 1.40, 1.48 and 1.59% for the year 2013, 2014, 2016 and pooled, respectively) were reported, it was maximum (1.85%) in Kesar for year 2015 (Malte 2011, Rodrigo and Herrero 2002, Kanzaria *et al.* 2015b) [13, 20, 10].

The significant differences in fruit weight, pulp and peel weight were found in different mango varieties. The maximum fruit weight was reported in Jamadar (233.99, 251.69, 251.99 and 247.36g for all the year and pooled data, respectively except during 2014). It was the highest for Kesar (258.75g) in the year 2014. The maximum pulp weight was reported in Jamadar (163.18, 178.54 and 176.55 g for the year 2013, 2015 and 2016, respectively. It was found maximum in the fruits of Kesar (191.00 and 174.84 g) for the year 2014 and pooled respectively. The significant differences in peel and stone weight were found in different mango varieties which might be due to its varietal characters. The minimum peel weight was reported in mango variety Dudhpendo (27.41, 23.00, 28.80, 29.52 and 27.18g for all individual year and pooled data, respectively. It found at par with V_2, V3 for the year 2013 and 2015 and with V_2 for the year 2016 and pooled data. The minimum stone weight was reported in mango variety Dudhpendo (17.18, 19.40, 17.53, 18.60 and 18.18g for all the years and pooled, respectively. The significant differences in length and width of fruit were observed in different mango varieties which might be due to its varietal characters. Significantly the maximum fruit length was reported in Kesar (11.02 and 10.77cm) during the year 2013 and pooled data, respectively. It was maximum (10.68, 10.60 and 10.76cm) during the year 2014, 2015 and 2016, respectively and found at par with Jamadar variety of mango. The maximum fruit width was reported in Jamadar (6.94, 7.14, 7.14 and 7.24cm) during the individual year, respectively. It was significantly higher (7.12cm) in pooled, respectively (Ravi *et al.* 2002, Meera *et al.* 2017 and 2018, Bhad *et al.* 2017, Kanzaria *et al.* 2015b, Disha *et al.* 2018) [19, 16, 15, 1, 10, 3]

The significant differences in number of fruits per plant were observed in different mango varieties. The maximum numbers of fruits were noted in Dudhpendo (366.60 and 336.60) during the year 2013 and 2015, respectively. It was significantly higher (293.00, 452.80 and 359.75) during the year 2014, 2016 and pooled data, respectively. It was reported at par with V_1 and V_2 during the year 2013 and 2015. The significant differences in yield were observed in different mango varieties. Significantly the maximum fruit yield/ plant (74.25, 75.85 and 74.72kg for the year 2013, 2015 and pooled data, respectively) for Kesar variety of mango was recorded. It was also maximum (67.51 and 83.98kg for the year 2014 and 2016, respectively) and found at par with V_3 (Table-12). Significantly maximum fruit yield/ha (7.42, 6.75, 7.59, 8.40 and 7.54t for the respective year and pooled data) was noted for Kesar except for the year 2016 which was at par with V_3. The significant difference in the HUE was noticed among the mango varieties (Oppenheimer 1947, Uddin and Amin 1995, Kanzaria *et al.* 2017, 2015d, Farheen *et al.* 2019) [17, 21, 8, 9]. The maximum HUE (7.11, 7.21, 7.04 and 6.75 kg/ha/ºday for the year 2013, 2015, 216 and pooled data, respectively) was achieved by mango variety Kesar. Though, it was found the highest for Jamadar (5.64 kg/ha/ºday) but found at par with Kesar variety. The highest HTU (13155.72 ºday hrs) and PTU (26613.46 ºday hrs) during BDS and similarly at maturity (11942.33 ºday hrs) and PTU (12182.69 ºday hrs) were reported in Kesar. But for flowering and fruit set the highest HTU (7471.90 and 1111.24 ºday hrs) and PTU (9973.37 and 139.14 ºday hrs), respectively were recorded for V_4 (Rajan 2008, Kanzaria *et al.* 2015a and 2015b) [18,7, 10].

Table 1: Days and GDD required for flowering and fruit set in different mango varieties (Pooled data of four years)

Variety	Days and GDD required for BDS*		Days and GDD required for flowering**		Days and GDD required for fruit set	
	Days	GDD	Days	GDD	Days	GDD
V_1- Kesar	168.55	1527.63	86.95	397.23	23.14	121.87
V_2- Alphonso	169.30	1532.24	84.73	390.23	21.76	125.38
V_3- Jamadar	165.75	1511.02	85.06	387.39	21.78	113.18
V_4- Dudhpenda	183.55	1564.72	98.74	440.15	25.50	159.59
S.Em.±	4.32	--	1.80	--	0.50	--
C.D. at 5%	12.28	--	5.12	--	1.44	--
C.V.%	11.24	--	9.06	--	9.80	--
Interaction	**Y x T**					
S.Em.±	8.63		3.60		1.00	
C.D. at 5%	NS		NS		NS	
	* Cutoff date was 1st July of respective year.					
	** Cutoff date was 1st November of respective year.					

Table 2: Days and GDD required for fruit development and maturity in different mango varieties (Pooled data of four years)

Variety	Days and GDD required for attaining pea stage		Days and GDD required for attaining marble stage		Days and GDD required for maturity	
	Days	GDD	Days	GDD	Days	GDD
V_1- Kesar	21.63	124.08	40.95	371.44	97.65	1123.83
V_2- Alphonso	22.68	159.90	46.08	409.32	104.58	1161.22
V_3- Jamadar	22.73	137.35	46.88	370.89	104.33	1129.25
V_4- Dudhpenda	31.33	321.00	53.48	570.22	112.75	1205.38
S.Em.±	0.64	--	2.08	--	1.71	--
C.D. at 5%	1.83	--	6.64	--	4.87	--
C.V.%	11.71	--	8.75	--	7.31	--
Interaction	**Y x T**					
S.Em.±	1.28		1.833		3.42	
C.D. at 5%	NS		NS		NS	

Table 3: Fruit set per cent and fruit characters in different mango varieties (Pooled data of four years)

Variety	Fruits (%) at pea	Fruits (%) marble stage	Fruit weight (g)	Pulp weight (g)	Peel weight (g)	Stone weight (g)	Fruit length (cm)	Fruit width (cm)	No. of fruits/ plant	Yield/ plant (kg)
V_1- Kesar	12.96	1.50	237.45	174.84	39.58	22.78	10.77	6.81	318.55	74.72
V_2- Alphonso	10.73	1.29	203.58	142.78	35.40	24.89	8.94	6.39	304.30	61.50
V_3- Jamadar	14.41	1.59	247.36	173.40	48.21	25.34	9.78	7.12	268.53	64.33
V_4- Dudhpenda	13.04	1.17	148.86	104.90	27.18	18.18	6.63	6.25	359.75	53.68
S.Em.±	0.32	0.029	3.72	2.77	0.85	0.39	0.19	0.10	11.01	1.65
C.D. at 5%	0.92	0.08	10.58	7.88	2.43	1.09	0.55	0.29	35.22	4.71
C.V.%	11.28	9.48	7.95	8.32	10.27	7.56	9.60	6.95	10.10	11.67
Interaction	**Y X T**									
S.Em.±	0.64	0.058	7.43	5.54	1.71	0.77	0.39	0.20	14.12	3.31
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	40.18	NS

Table 3: Fruit yield and Heat Use Efficiency in different mango varieties (Pooled data of four years)

Variety	Yield/ ha (t/ha)	Heat Use Efficiency (kg/ha/°day)
V_1- Kesar	7.54	6.75
V_2- Alphonso	6.14	5.32
V_3- Jamadar	6.62	5.86
V_4- Dudhpenda	5.34	4.44
S.Em.±	0.17	0.29
C.D. at 5%	0.48	0.93
C.V.%	11.65	11.83
Interaction	**Y X T**	
S.Em.±	0.33	0.30
C.D. at 5%	NS	0.84
	HUE: Heat Use Efficiency in kg/ha/°day	

Table 4: Meteorological parameters for different mango varieties (Pooled data of four years)

Varieties	BDS		Flowering		Fruit set		Maturity	
	HTU	PTU	HTU	PTU	HTU	PTU	HTU	PTU
V_1- Kesar	13155.72	26613.46	6513.8	8785.43	1048.72	1394.86	11942.33	12182.69
V_2- Alphonso	7276.01	18721.82	6790.60	9125.92	983.71	1310.45	11005.41	11905.40
V_3- Jamadar	6995.14	18512.75	6571.30	8363.04	960.87	1286.57	11245.04	11345.70
V_4- Dudhpenda	7954.69	19333.28	7471.90	9973.37	1111.24	1397.14	10584.11	11162.25

HTU: Helio-Thermal Unit (GDD x Actual BS Hours in ^{o}day hrs)
PTU: Photo Thermal Unit (GDD x Maximum possible BS Hours in ^{o}day hrs)

Conclusion

On the basis of the results and interpretation TT is inferred that the GDD have direct influence on flowering to fruit maturity, but not on fruit characters. The GDD requirements of different varieties were found distinct. A mango variety Kesar requires low GDD for maturity with higher Heat Use Efficiency and Photo Thermal Unit.

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