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Temperature effects on phenological development and yield of Snapmelon

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Abstract

The aim of the study was to workout relationship between phenological development and yield of snapmelon in relation to temperature that could be predicted with easily obtainable weather station data and used as an aid in projecting harvest dates along with potential yield. Temperature is one of the most important elements of the climate which determines the potential productivity level of a crop. Heat unit requirement was used for characterizing the thermal response in snapmelon (*Cucumis melo* var. *momordica*) for the assessment of yield potential of a crop in different growing environments. A field experiment was carried out to find out the phenophasic development and yield attributes of snapmelon in relation to ambient air temperature and to find out suitable varieties for commercial cultivation of snapmelon with eight genotypes as influenced by three sowing dates. The studies revealed that the snapmelon sown on 22nd January, accumulated lower number of growing degree days with higher heat use efficiency, among the genotypes tried. Efficiency of converting thermal regime to yield formation was higher when the crop was sown on 22nd January and it decreased with the delayed sowing. A sharp decline in crop duration as well as days to flowering occurred with the rise in temperature irrespective of the varieties. Where as fruit weight, fruit diameter and fruit length were varietal characteristics and not influenced by the different environmental conditions. Genotype IC-102K-Bh (V_4) was found to be the best cultivar with regard to early female flower initiation and yield as the cultivar utilized the thermal regime for yield most efficiently.

Key words: Temperature, phenophases, growing degree days, yield, snapmelon.

Introduction

It is often difficult for commercial growers of many important horticultural crops to select planting dates that result in desired harvest date windows; this is mainly due to temperature differences among growing seasons. Temperature is a major environmental variable influencing crop development. The occurrences of different phenological events during the growing season of any crop and the effect of temperature on plant growth and development can be inferred using accumulated heat units or growing degree days (GDD) or thermal growth rate (Baker and Reddy, 2001). Growing degree days accumulate various combinations of daily temperature above the threshold temperature during the growing season of a crop. Real time to a given developmental event is approximately linearly related to temperature in the range between a base and optimum temperature (Pandit *et al.*, 2001).

Agronomic application of temperature effect on plants in the growing degree days concept has been variously applied to correlate phenological development of any crop to predict maturity dates. Apart from this, heat use efficiency (HUE) (*i.e.* efficiency of utilization of heat energy in terms of the final yield) is another important aspect which has practical utility. Efficiency of heat energy conversion depends upon genetic factors and environmental variability. Snapmelon (*Cucumis melo* var. *momordica*) is one of the important but under utilized cucurbits which has good potential to be utilized as vegetable as well as dessert fruit. There is almost no recommended variety released in India for this crop and very little information available regarding its phenological development in relation to temperature. Considering the facts, the experiment was conducted to find out the phenophasic development and yield attributes of snapmelon in relation to ambient air temperature and to find out suitable varieties for commercial cultivation in autumn-winter and spring-summer seasons along with their optimum sowing time in '*Gangetic*' alluvial zone of West Bengal.

Materials and methods

A field experiment was carried out during autumn-winter and spring-summer seasons, 2009-10 at the Central Research Farm, Goyeshpur, Bidhan Candra Krishi Viswavidyalaya, West Bengal to quantify GDD requirement of different phenophases of snapmelon with eight genotypes *viz.*, IC-K2M-T1 (V_1), IC-KP-Long (V_2), IC-82K-Pr (V_3), IC-102K-Bh (V_4), IC-BA-2K (V_5), IC-K2M-T2 (V_6), IC-0101-Mp (V_7) and IC-82K-Tg (V_8) as influenced by three sowing dates *viz.*, 22nd November (S_1), 22nd January (S_2) and 22nd March (S_3) with three replications in Randomized Block Design. For determining the role of ambient temperature, the growth phases of snapmelon were divided into eight phenophases *viz.*, sowing to first male flowering (P_1), first male flowering to first female flowering (P_2), first female flowering to first fruiting (P_3), first fruiting to first harvesting (P_4), first harvesting to last harvesting (P_5), first male flowering to first fruiting (P_6), first male flowering to first harvesting (P_7) and sowing to first harvest (P_8). Recommended agronomic practices were adopted to raise the crops. Five randomly selected plants per plot were taken to record observations on different yield and yield attributing characters. The experimental site was situated

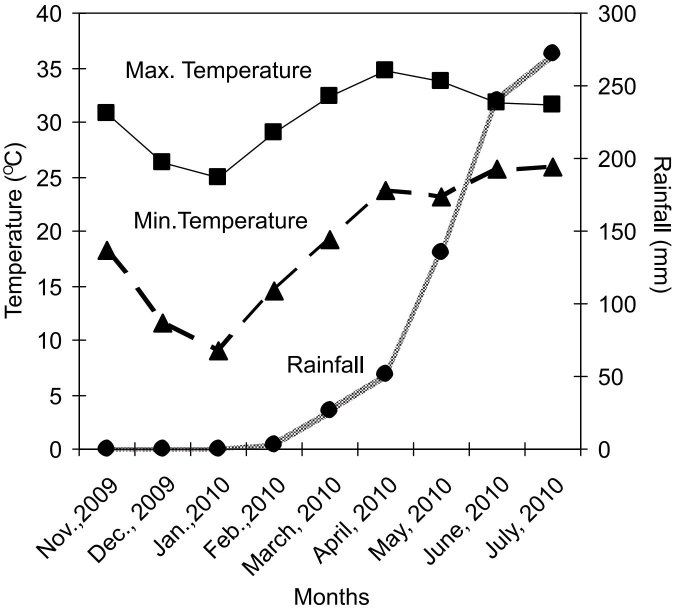

Fig. 1. Weather data during the experimental period. Daily temperature and rainfall were recorded and presented as monthly average

at '*Gangetic*' alluvial zone under humid subtropical climate. Maximum and minimum temperature and average rainfall (Fig. 1) during the growing period of snapmelon was recorded from meteorological observatory of the University.

Heat unit concept has been applied to correlate phenological development in crops (Mills, 1964; Nuttonson, 1955). Accumulated growing degree days (GDD) was computed by the following formula:

$$GDD = \{(T_{max} + T_{min})/2\} - Tb\ ^{0}Cd$$

Where, T_{max} - daily maximum temperatures

T_{min} - daily minimum temperatures

Tb - base temperature below which physiological activities are ceased. For snapmelon, Tb is considered as 12 ^{0}C following Jenni *et al.* (1996) and Pardossi *et al.* (2000).

Heat use efficiency (HUE) was computed to compare the relative performance of different cultivars with respect to utilization of heat, using the formula:

$$HUE = \frac{\text{Snapmelon yield (kg hectare}^{-1})}{\text{Accumulated growing degree days (}^{0}\text{Cd)}}$$

Results and discussion

Accumulated growing degree days (^{0}Cd) during different phenophases: In order to quantify thermal environment during different phenophases of snapmelon accumulated growing degree days (GDD) corresponding to different phenophases are presented in Table 1. Variability in accumulated GDD was almost similar in P_1, P_2 and P_3 stage. It was noted that when GDD values were combined for different phenophases the coefficient of variability over cultivars and dates of sowing, gradually reduced. When accumulated GDD obtained by different varieties were studied, it revealed that this value varied with dates of sowing at a particular phenophase. However, cultivars in general, recorded consistently higher accumulated GDD when sown on 22nd of March when phenophases one to four were combined. But due to variation in P_5 phenophase in relation to dates of sowing this trend was not persistent for all the variation when accumulated GDD from sowing to last harvest were considered.

Response of crop duration to temperature: Daily maximum and minimum air temperatures through out the growing period were recorded during the experiment. As anticipated, the range of sowing dates resulted in a wide range of air temperatures over the respective growing seasons, from minimum daily air temperatures below 5.6 ºC early in the experiment, to maximum daily air temperatures exceeding 38 ºC later in the experiment. Total crop duration of different varieties in response to average seasonal temperature is presented in Fig. 2. Duration of individual varieties indicate that the snapmelon crop took 96 to 172 days to mature with V_5 took the lowest (96 days) and V_7 took the maximum number of days (172 days). All the varieties tested showed a gradually reducing trend in the number of days to mature as the sowing was delayed beyond 22nd of November and this difference in total duration was mostly attributed to the difference in duration of sowing to first male flowering stage. On an average every 1^{o}C rise in temperature the crop duration was reduced by 8.5 days.

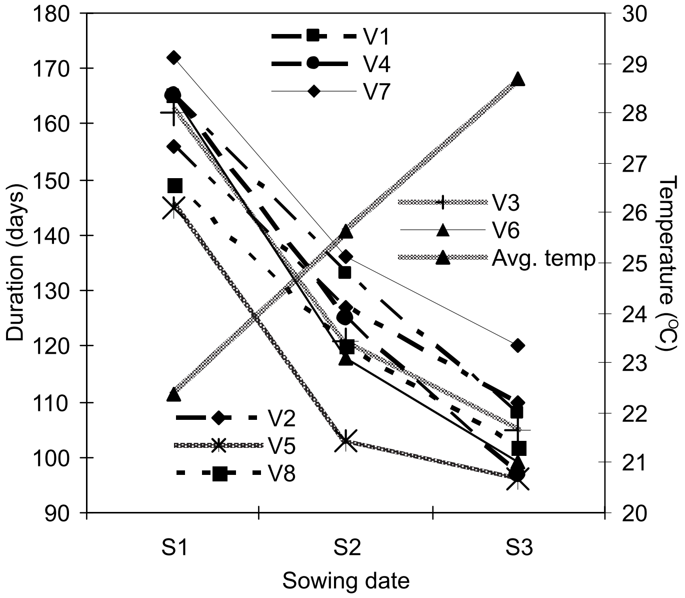

Fig. 2. Effect of mean growing temperature on crop duration of different cultivars at various sowing dates

Table 1. Accumulated growing degree days during different phenophases of snapmelon

Sowing dates	GDD (^{0}Cd) for different phenophases								
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	Total crop period
S_1	540.35	135.1	93.15	548.31	351.6	228.27	776.58	1316.9	1668.4
S_2	527.66	178.02	96.91	494.92	370.46	274.93	713.97	1220.95	1664.1
S_3	771.7	155.05	90.61	444.45	295.05	226.23	690.03	1452.58	1756.7
CV%	22.7	22.6	22.9	18.9	14.7	20.7	13.7	12.3	

However, when the mean air temperature data over the entire phenophases were averaged, it was observed that there was not much variation among the cultivars as exposure to thermal environment was concerned. With reference to sowing dates mean air temperature to which the crop was exposed was in the order $S_1 < S_2 < S_3$ and this trend was consistent for all the varieties tested.

Yield and yield attributing characters in relation to sowing dates and accumulated GDD: A perusal of the data as presented in Fig. 3 revealed that irrespective of the genotypes, days required for first male flower appearance vary significantly over the different sowing dates. The lowest days required for first male flower initiation under S_3 followed by S_2. When varietal response was studied it was clear that V_5 needed the lowest number of days (average of three sowing dates) to initiate first male flower followed by V_4, whereas V_7 took the longest time. The interaction effect of genotype × sowing date was also significant.

The similar trend was observed for days to 1st female flower initiation *i.e.* lowest days required for female flower production over the varieties in S_3 condition followed S_2 condition (Fig. 4). Duration of both 1st male and female flower initiation significantly reduced with the increase of accumulated GDD for their respective periods, irrespective of the varieties and the finding is supported by Sedgley and Buttrose (1978) in watermelon. Days to first female flower also varied significantly among genotypes. The lowest numbers of days were needed by the V_4 followed by V_5 whereas V_7 required maximum number of days to initiate first female flower. The interaction effect of genotypes and environment was found to be significant.

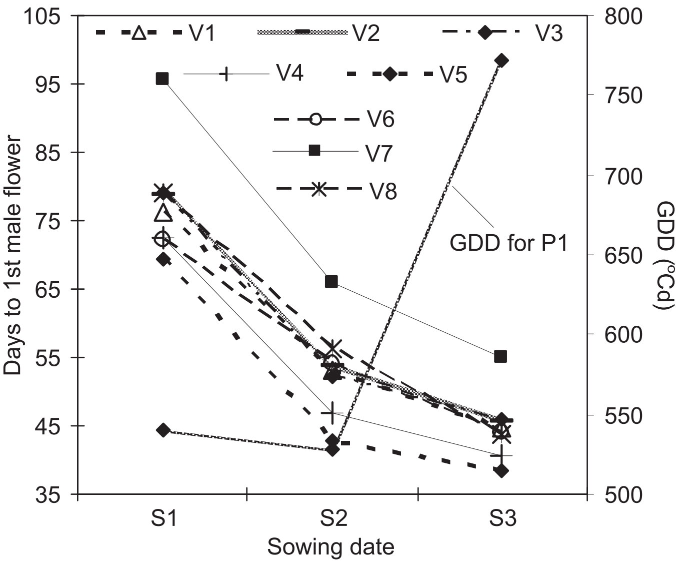

Fig. 3. Days to 1st male flower vs. GDD for P_1 at three different sowing dates

Average fruit length, fruit diameter and fruit weight of 8 different lines is plotted against three different sowing dates in Fig. 5. The summarized results showed that sowing dates had no significant effect on these three characters and sowing dates were at par among themselves. Though these characters varied significantly among genotypes. It clearly indicated that average fruit weight, fruit diameter and fruit length were varietal characteristics and not influenced by the different environmental conditions provided in the present experimental set up. The results are supported by Kohli and Pathania (1989) on Sarda melon.

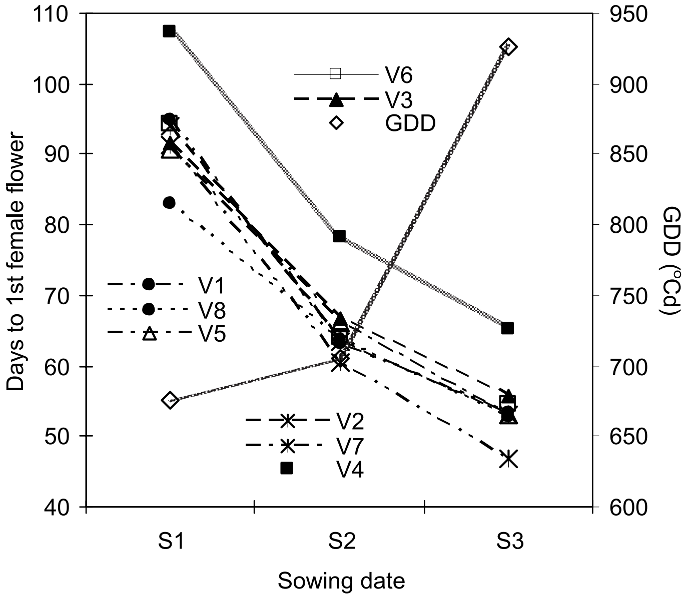

Fig. 4. Days to 1st female flower vs. GDD for P_2 at three different sowing dates

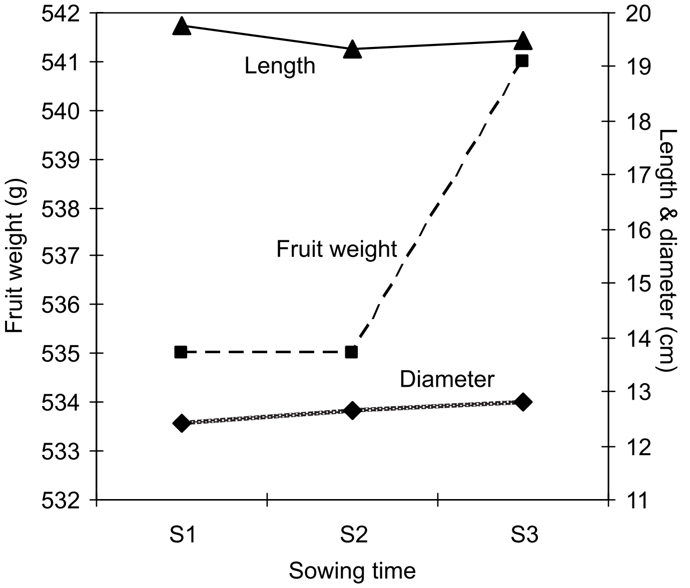

Fig. 5. Effect of different sowing dates on average fruit weight, diameter and length of different cultivars. Each datum point represents the average of 8 cultivars. Effect of sowing dates and interaction between varieties and sowing dates were non significant while cultivar varies significantly among themselves for all the three characters

Effects of sowing on fruit number/plant and fruit yield/ha in relation to accumulated GDD at different sowing date are presented in Fig. 6 and Fig. 7, respectively. Fruits per plant of the eight genotypes varied significantly over the different accumulated GDD. Highest numbers of fruits per plant were observed under S_2 condition followed by S_1 condition. This character also did vary significantly among genotypes. Highest mean number of fruits (7.90) over the sowing dates were produced in the genotype V_4 followed by V_1 (7.27).

The results of mean yield per ha showed that effect of accumulated GDD at varying sowing dates had a significant role in the yield of snapmelon (as the dates of sowing were critically different among themselves, irrespective of varieties). S_2 produced maximum yield and S_1 produced the lowest yield. Variety V_4 produced the

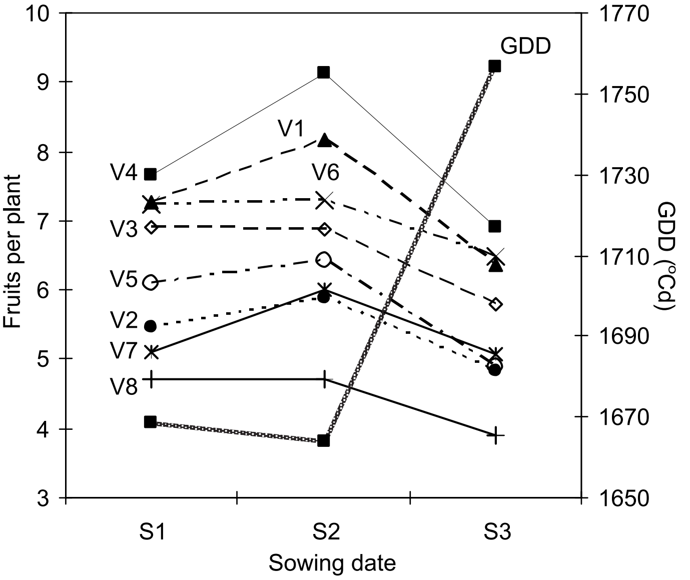

Fig. 6. Number of fruits per plant vs. GDD at three different sowing dates

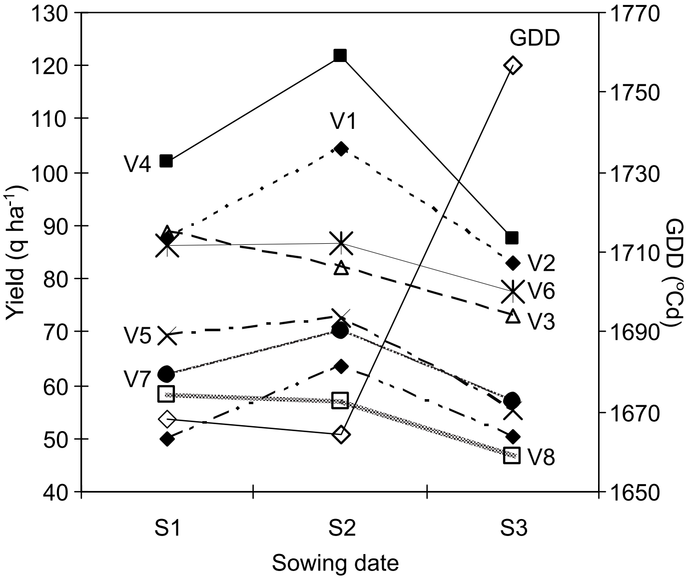

Fig. 7. Fruit yield per ha vs. GDD at three different sowing dates

maximum yield of 103.67 quintal of fruit (average over three sowing dates) which was superior to all other genotypes followed by the genotype V_1 with fruit yield of 91.60 quintals.

The cultivars did not differ significantly but sowing date had a large effect on yield and severely reduced yield in the last sowing date. The most likely explanation for this yield decline was mainly the result of a reduction in number of snapmelon produced since individual fruit weight (non significant to sowing date) had relatively more stable trend across sowing dates. It has been reported that reproductive physiology is much more sensitive to high temperature stress than vegetative growth in both rice (Baker and Allen, 1993), and cotton (Reddy *et al.*, 1995). In rice, spikelet sterility caused by high temperature is induced almost exclusively on the day of anthesis and temperatures greater than 35 ^{0}C for as little as 1 h at flowering can induce a high degree of spikelet sterility (Yoshida, 1981). In tomato, vegetative foliage has been shown to be fairly tolerant to high temperatures, but temperatures exceeding 30 to 35 ^{0}C result in poor reproductive development (Wolfe *et al.*, 1989). Reddy *et al.* (1992) examined the effects of high temperature on cotton fruit retention and found that a 3 week exposure to 40 ^{0}C for 2 or 12 h per day resulted in 64 or 0% of the bolls, respectively, being retained on the plants. In the present study, it is also possible that the higher air temperatures later in the season may have had a negative impact on bee activity and pollination of flowers.

The reductions in the length of the growing season or crop duration with sowing date (Fig. 2) probably also contributed to reduced yield of snapmelon. Crop growth is inherently coupled with photosynthetic gains and respiratory losses. It is usually assumed that maintenance respiration increases with increasing temperature while growth respiration varies with temperature only as relative growth rate varies with temperature. Nevertheless, crop ontogeny directly influences growth and yield through growth duration, which determines the amount of solar radiation the crop can intercept (Horie, 1994). In melons, a long warm and preferably dry weather with plenty of sunshine yield a good crop. Abundant rain, fruit fly and related moisture-conducive diseases may significantly reduce the yield of snapmelon in late sowing (S_3) condition as it is clear from weather parameters.

Other possible explanation of the differences among sowing dates on yield attributing characters is a photoperiod effect. In cereal crops, it is apparently influenced by the rate of change of day length at crop emergence (Baker and Gallagher, 1983) but the exact nature of this relationship has been questioned by others (Ritchie, 1991). To date, we are unaware of any published reports on the effects of photoperiod on snapmelon development. Clearly, this is an area in need of further research.

Heat use efficiency (kg/ha/ ^{0}Cd) of different genotypes over dates of sowing: The efficiency of snapmelon in using thermal regime towards formation of economic yield is presented in Table 2. It is revealed that the cultivar V_4 was most efficient in utilizing thermal regime for yield (HUE = 6.1 kg ha^{-1} ^{0}Cd^{-1}) followed by cultivar V_1 (5.1 kg ha^{-1} ^{0}Cd^{-1}) and V_6 (5.00 kg ha^{-1} ^{0}Cd^{-1}). Cultivars V_2, V_7 and V_8 were however, assessed to be less efficient in utilizing heat units. It was interesting to note that though the thermal environment from sowing to harvesting for all the cultivars tested were, in general, cooler when the crop was sown on 22nd November (S_1), the efficiency of converting thermal regime to yield formation was higher when the crop was sown on 22nd January (S_2). And this trend was consistent among all the genotypes with further delay in sowing from 22nd January, the heat use efficiency was in general lower for the genotypes.

Correlation between yield and parameters during different phenophases: In order to find out critical weather parameter corresponding to different phenophases which influences yield,

Table 2. Heat Use Efficiency (HUE) of different varieties of snapmelon

Line	Heat Use Efficiency (kg ha^{-1} ^{o}Cd^{-1})			
	S_1	S_2	S_3	Mean
V_1	5.0	5.7	4.6	5.1
V_2	3.1	3.6	2.7	3.2
V_3	5.2	5.0	4.2	4.8
V_4	5.8	7.2	5.4	6.1
V_5	4.9	5.3	3.4	4.5
V_6	4.9	5.5	4.9	5.0
`V_7	3.3	3.7	2.8	3.3
V_8	4.0	3.5	2.7	3.4

Table 3. Correlation between yield of snapmelon and parameters (GDD, mean temperature and duration)corresponding to different phenophases

Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
GDD	-0.43	0.16	0.06	0.5^*	0.32	0.27	0.51^*	-0.03
Mean Temp.	-0.28	-0.15	0.20	0.01	-0.08	-0.05	-0.08	-0.19
Duration	-0.01	0.2	0.25	0.39	0.26	0.26	0.40	0.15

correlation coefficient were computed and tested for significance. It is revealed from the Table 3 that accumulated growing degree days from first fruiting to first harvest and first male flower to first harvest was positively and significantly correlated (0.5 to 0.51, respectively) with fruit yield at harvest which indicated that the snapmelon crop prefers higher temperature for fruit formation. However, mean temperature as well as duration of different phenophases were not substantially associated with fruit yield at harvest of snapmelon.

Though the sowing dates and the genotypes did not interact as a unit for better yield, the sowing time had a great influence in determining the final yield of snapmelon. The major contributing factor was temperature which quantitatively varies with growing seasons. Reproductive physiology of snapmelon was negatively affected to high temperature stress that had been witnessed by reduction of fruit number and yield in crops sown on 22nd March. Whereas certain fruit characteristics like fruit weight, diameter or length remained more stable throughout the sowing dates and probably governed by genotypes rather than temperature. Crop duration which had a direct positive influence on growth and yield was also reduced with the rise in temperature in later sowing date. Sowing snapmelon during the third week of January will be the best for a good produce. Accumulated growing degree day from the initiation of male flower to first harvest (P_7) positively influenced the fruit yield when pest attack and disease incidence did not limit growth. When snapmelon was sown up to the end of January increasing mean air temperature at different phenophases helped in increasing fruit yield. Cultivar V_4 was found to be the best with regard to early female flower initiation and yield and it also utilized the thermal regime for yield most efficiently. This genotype can be utilized for commercial purpose as well as in the future breeding programme to get good recombinants in advance generation.

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