

## Thermal requirements for flowering and fruit yield attainment in advance lines of okra

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### ABSTRACT

The field experiment comprising 12 advance lines of okra was carried out to assess thermal requirement for flowering and total fruit yield during rainy seasons at CCS Haryana Agricultural University, Hisar. The results revealed that okra crop required 762.4 day°C accumulated heat units for flowering and 1600.5 day°C accumulated heat units for total fruit yield production. Advance line HRB 108-2 required minimum for flowering (664.4 day°C) and highest 1644.8 day°C for total fruit production with better thermal use efficiency (9.1 kg ha<sup>-1</sup> °D) indicating its suitability for early and more fruits availability for longer period. Fruit yield production showed significant positive association with heat unit requirement in all the years. The R<sup>2</sup> values of regression equation could explain the variation between 63-87% of the total variation in fruit production in okra.

**Keywords:** Okra, thermal requirement, advance line, thermal use efficiency

Okra, *Ablemoschus esculentus* (L.) Moench, is an economically important vegetable crop grown in tropical and subtropical parts of the world. It is propagated by seeds and has duration of 90-100 days but its plants are characterized by indeterminate growth. The plants usually bear their first flower one to two months after sowing. Okra plants continue to flower and to fruit for an indefinite time depending upon the variety/hybrid, season, biotic and abiotic factors. The fruits grow quickly after flowering and greatest increase in fruit length and diameter occurs during 4<sup>th</sup> to 6<sup>th</sup> day after pollination and at this stage fruits are fibrous, immature and high in mucilage, which are most often plucked for consumption. Generally the fiber production in fruits starts from 6<sup>th</sup> day onwards of fruit formation and sudden increase in fiber content from 9<sup>th</sup> day is observed (Nath, 1976). Okra requires a long, warm and humid growing period. It can be successfully grown in hot humid areas. For normal growth and development a temperature between 24°C and 28°C is preferred. A higher temperature hastens the growth of plant, but delays the flowering. But at higher temperature beyond 40-42°C, flowers may desiccate and drop, causing yield losses. Wang (1960) reported that duration of a particular stage of growth was directly related to temperature and this duration for particular species could be predicted using sum of daily air temperatures or cumulative thermal requirement also known as Growing Degree Days (GDD) or Heat Units (HU). Growing degree

days are a measure of heat accumulation used to predict phenological development rates such as the date that a flower will open or a crop will reach maturity and further to explore the agro-climatic potential of a region (Pandey and Shekh, 1999). Thus air temperature based agrometeorological indices like Growing Degree Days, Heliothermal units and Photothermal units and the thermal or heat use efficiency can successfully be used for describing phenological behavior and growth parameters like biomass production, fruit yield etc. in relative terms (Hundal and Kingra, 2000; Hundal *et al.*, 2003; Neog and Chakravarty, 2005; Kumar *et al.*, 2008). Therefore, present field experiment was conducted to study and establish thermal requirements for attaining flowering and fruit yield attributes in advance line of okra.

### METARIALS AND METHODS

The present experiment comprising of twelve advance lines of okra was carried out for three consecutive years during rainy seasons of 1997, 2008 and 2009 at Research Farm, CCS Haryana Agricultural University, Hisar (29°10'N; 75°46'E and 215 meter above sea level) to study the thermal requirements for flowering and total fruit production attributes. The climate of Hisar region is comparatively hot and it receives about 360 mm of rainfall. During the crop growing period (July-October) of the experiment, the meteorological parameters viz., average maximum and minimum temperature and total rainfall

**Table 1 :** Thermal requirement (day °C) to attain 50% flowering in okra advance lines

S.No	Advance line	1 <sup>st</sup> Year	2 <sup>nd</sup> Year	3 <sup>rd</sup> Year	Mean
1.	HRB-101-1	644.4	751.6	830.2	742.1
2.	HRB- 102-1	671.5	780.1	857.1	769.6
3.	HRB- 105-1	644.4	752.1	815.7	737.4
4.	HRB- 107-2	642.9	781.6	830.2	751.6
5.	HRB- 108-2	619.1	699.6	674.6	664.4
6.	HRB- 115-1-1	630.1	753.6	812.9	732.2
7.	HRB- 118-3	794.1	1088.6	813.5	898.7
8.	HRB- 124-1-1	732.7	942.6	784.5	819.9
9.	HRB- 128-1	658.2	780.6	817.4	752.1
10.	HRB- 146-2	633.1	752.1	829.1	738.1
11.	HRB- 147-2	672.5	781.6	921.4	791.8
12.	HRB- 153-1	656.5	780.6	813.9	750.4
Mean		666.6	803.7	816.7	762.4
CD at 5%		102.7	CV=7.1		

recorded were 34.5, 34.9 and 36.9°C, 23.6, 24.9 and 25.3°C and 480.9, 470.5 and 150.8 mm during the experimental seasons, respectively. Seeds of the twelve advance lines were sown on 8<sup>th</sup> July, 6<sup>th</sup> July and 27<sup>th</sup> June in three consecutive rainy seasons, respectively in randomized block design with three replications. The recommended package and practices by the University were adopted for all genotypes to raise healthy crop. The observations for days taken to 50 per cent flowering (sowing date to first flower appearance on 50 % plants in each genotype) and total fruit yield. Fruit setting in okra takes place on the same day of pollination as the fertilization process completes in 4-6 hours. The daily agrometeorological data recorded at Agrometeorological Observatory situated nearby in the Research Farm of CCS Haryana Agricultural University, Hisar were used for calculation of thermal requirements for attaining different phenophases in okra. Different agrometeorological indices and thermal use efficiency were calculated on daily basis and summation were made for different stages separately from sowing to last picking of fruits.

Thermal units or growing degree days (GDD) were calculated by taking the average of the daily maximum and minimum temperatures compared to a base

**Table 2 :** Thermal requirement (day°C) to attain final fruit yield in okra advance lines

S.No	Advance line	1 <sup>st</sup> Year	2 <sup>nd</sup> Year	3 <sup>rd</sup> Year	Mean
1.	HRB-101-1	1708.4	1566.1	1451.7	1575.4
2.	HRB- 102-1	1656.4	1593.2	1425.1	1558.2
3.	HRB- 105-1	1755.5	1671.9	1415.7	1614.4
4.	HRB- 107-2	1794.8	1703.7	1387.5	1628.7
5.	HRB- 108-2	1811.2	1722.8	1400.4	1644.8
6.	HRB- 115-1-1	1765.4	1623.0	1472.1	1620.2
7.	HRB- 118-3	1589.1	1541.8	1359.6	1496.8
8.	HRB- 124-1-1	1736.0	1572.5	1439.3	1582.6
9.	HRB- 128-1	1745.9	1632.8	1457.0	1611.9
10.	HRB- 146-2	1836.2	1716.4	1444.3	1665.6
11.	HRB- 147-2	1698.7	1566.1	1459.6	1574.8
12.	HRB- 153-1	1776.1	1688.5	1434.3	1633.0
Over all Mean		1739.5	1633.2	1428.9	1600.5
CD at 5%		75.0	CV= 2.75		

temperature,  $T_{base}$ , (usually 10 °C for summer season crops) as suggested by Monteith (1984) using the formula:

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

The thermal use efficiency was computed (kg ha<sup>-1</sup> per degree) to compare the relative performance of different genotypes with respect to utilization of heat using the below formula:

$$\text{Thermal use efficiency (TUE)} = \frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{GDD (day}^{\circ}\text{C)}}$$

The correlation and predictive regression relation model were also worked out between thermal indices and total fruit yield of different advance lines of okra.

## RESULT AND DISCUSSION

### Thermal requirements

The thermal requirements of twelve advance lines of okra for flowering as well as fruit production are presented in Table 1 and 2. Among all the advance lines, two lines viz., HRB 118-3 and HRB 124-1 used highest thermal units of 898.7 and 819.9 day°C, respectively in attaining the 50% flowering. HRB 108-2 required lowest

**Table 3 :** Thermal use efficiency ( $\text{kg ha}^{-1}\text{°D}^{-1}$ ) of advance lines in okra

S.No	Advance line	1 <sup>st</sup> Year	2 <sup>nd</sup> Year	3 <sup>rd</sup> Year	Year	Mean
1.	HRB-101-1	8.6	8.8	9.0		8.8
2.	HRB- 102-1	8.2	9.2	8.4		8.6
3.	HRB- 105-1	8.9	9.7	8.2		8.9
4.	HRB- 107-2	9.1	10.0	7.6		8.9
5.	HRB- 108-2	9.4	10.1	7.8		9.1
6.	HRB- 115-1-1	8.6	9.4	9.4		9.1
7.	HRB- 118-3	5.1	5.6	7.6		6.1
8.	HRB- 124-1-1	8.8	8.9	7.4		8.3
9.	HRB- 128-1	8.9	9.4	9.2		9.2
10.	HRB- 146-2	9.5	10.2	8.8		9.5
11.	HRB- 147-2	8.6	8.8	8.0		8.4
12.	HRB- 153-1	9.1	9.8	8.7		9.2
	Over all mean	8.6	9.2	8.3		8.7

CD at 5% 1.2 CV= 8.0

cumulative thermal unit of 664.4  $\text{day}^\circ\text{C}$  in attaining 50% flowering stage. Rest of lines consumed thermal units ranging from 732.2 (HRB 115-1) to 971.8  $\text{day}^\circ\text{C}$  (HRB 147-2) to reach 50% flowering stage (Table 1).

The advance line HRB 146-2 utilized highest amount of accumulated thermal unit (1665.6  $\text{day}^\circ\text{C}$ ) to produce total fruit yield and was closely followed by HRB 108-2 (1644.8  $\text{day}^\circ\text{C}$ ) and HRB 153-1 (1633.0  $\text{day}^\circ\text{C}$ ) (Table 2). These advance lines produced maximum fruit yield ( $\text{kg ha}^{-1}$ ) in similar order and also consumed lowest heat units for attaining flowering indicating their suitability for early and more fruits available for longer period. This might be due to less number of days taken for flowering and longer fruiting period. On the other hand, advance line HRB-118-3 consumed less thermal units for total fruit yield and more units for flowering owing to more number of days taken for flowering and shorter fruiting period. It is also interesting to note that line HRB 124-1 used more units for both flowering and total fruit yield. Though, different advance lines exhibited variations in thermal use consumptions in different growing seasons under experiment, reason being prevailing weather conditions and its variability, but at the same time indicating availability of fruits in different time period in

**Table 4 :** Regression equation for fruit yield prediction in okra

Year	Regression equation	R <sup>2</sup> value	SE	Correlation with fruit yield
1 <sup>st</sup> Year	$Y = -416.63 + 0.325TU$	0.87	0.04	0.93**
2 <sup>nd</sup> Year	$Y = -377.084 + 0.323TU$	0.75	0.06	0.86**
3 <sup>rd</sup> Year	$Y = -286.800 + 0.284TU$	0.63	0.07	0.79**
Pooled	$Y = -441.261 + 0.363TU$	0.79	0.04	0.94**

the market for consumers. On average okra required accumulated thermal units of 762.4  $\text{day}^\circ\text{C}$  for flowering and 1600.5  $\text{day}^\circ\text{C}$  for final fruit yield. The results are well corroborated by finding of Debosthali *et al.*, (2005).

#### **Thermal use efficiency**

Efficiency of thermal energy conversion for fruit yield depends upon the genetic make up of the plant, flowering time and fruiting period of the genotype. Thermal use efficiency derived (Table 3) thereby was maximum (9.5) for advance line (HRB 146-2) also accumulating the highest thermal units for producing final fruit yield. Other advance lines *viz.*, HRB 128-1(9.2), HRB 153-1(9.2), HRB 108-2 (9.1) and HRB 115-1 (9.1) also closely followed in thermal use efficiency for fruit yield however, these lines accumulated different amount of cumulative thermal units ranging 1611.9 to 1644.8  $\text{day}^\circ\text{C}$ . The lowest heat use efficiency (6.1) was expressed by the advance line HRB 118-3. Rest of the other advance lines had thermal use efficiency ranging from 8.3 to 8.9. It is evident here that high yielding advance lines accumulated high amount of thermal units and are more efficient users of thermal energy than the late flowering and poor yielder advance lines. The probable reason might be short duration of fruiting period due to late flowering and early termination of final fruit yield.

#### **Correlation and prediction model**

Regression model was developed for fruit yield prediction using fruit yield of the twelve advance lines for each year and pooled data along with accumulated thermal units by various lines during the period under experiment. Thermal units accumulated by advance lines during fruiting period were used for regression and simple correlation studies. The thermal unit required for total fruit yield in first ,second and third year showed positive

and significant correlation values of 0.93, 0.86 and 0.79, respectively with fruit yield, whereas pooled data showed 94 per cent variation in fruit yield due to accumulated thermal energy use. The estimation of regression models (Table 4), which revealed that model accounted for 87, 75 and 63 per cent of total variation as revealed by  $R^2$  values in fruit yield for the first, second and third year, respectively, whereas, the pooled data exhibited 79 per cent variability in fruit yield because of thermal unit consumption.

### CONCLUSION

There were genotypic differences for heat requirement and their use efficiency for flowering and final fruit production. However, okra in general required 762.4 day°C thermal units for flowering and 1600.5 day°C thermal units for total fruit yield production. Fruit production exhibited significantly positive association with thermal energy consumption.  $R^2$  values of regression equation of pooled data could explain 79 percent variability of total fruit production in okra under Hisar conditions. Thus, thermal requirements and their efficient utilization by okra genotypes may be used to assess the crop performance for developing and introducing a variety to a particular locality depending on the thermal environment so as to draw the maximum benefit from the market.

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