Growing degree days requirement of sesame (Sesamum indicum) in relation to growth and phonological development in Western Rajasthan

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SHORT COMMUNICATION

Growing degree days requirement of sesame (*Sesamum indicum*) in relation to growth and phonological development in Western Rajasthan

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ABSTRACT

Sesame (*Sesamum indicum*) is a short-day plant and generally requires fairly hot conditions for its optimum growth and yield. Crop growth and development are closely related with growing degree days. Therefore, growing degree days (GDD) requirement for different phenological stages of sesame cv. RT 127 was studied during the *kharif* seasons of 2010 and 2011 at the Research Farm of Central Arid Zone Research Institute, Jodhpur (Rajasthan). Plant height increased with accumulation of GDD and attained an height of 124 cm after receiving an accumulated GDD of about 1266 °C-day during 2010 and similarly, plant height of 132 cm was observed corresponding to 1240 °C-day accumulated GDD during crop season 2011. 80 leaves plant^{-1} were observed corresponding to an accumulated GDD of 970°C-day during crop season 2010 and 92 leaves plant^{-1} corresponding to 1094°C-day accumulated GDD during 2011. For initiation flowering stage, higher accumulation of GDD (852°C-day) was observed in 2011 as compared to 2010 (673°C-day) crop season. Higher amount of GDD was also observed for physiological maturity in 2011 than 2010. The significant difference in GDD in the year of normal and late sowing year was also proportionately reflected at 50 and 100% flowering. Hence, study revealed that amount of GDD received in sunny day plays an important role for crop growth and maturity rather than days after sowing. An effort on establishment of relationship between GDD and growth and development of sesame crop may be helpful in developing new varieties matching with shifting climatic patterns.

Key words: Arid zone crops, Growing degree days, Rainfed agriculture, Sesame

India is the largest producer of sesame (*Sesamum indicum* L.) accounting for 24% of world production. It is grown in 1.90 million hectares area in the country with total production and average productivity of 0.8 million tonnes and 426 kg ha^{-1}, respectively (DAC, 2012). It is basically a crop of the tropical areas, though its cultivation extends also to temperate areas. Abnormally higher temperature at the time of flowering and fruit setting may lead to premature yield, shedding of flowers and reduction in pollen sterility. Although sesame also grows well in long-day areas, it is generally considered a short-day plant. It flowers about 45 days under 10-hours day length.

Growing degree days (GDD) are frequently used as weather-based indicator for assessing crop phenology. Therefore, all growth and development stages of crop may be estimated more accurately on the basis of GDD rather than calendar method (Warthington and Hatchinson, 2005). The GDD can be calculated with the utilization of daily maximum and minimum air temperatures and the base temperature of a particular crop. The base temperature varies according to crop type and location. Sesame crop requires different amount of growing degree days for growth and development. Different sowing dates create different sets of environmental conditions from seedling emergence to physiological maturity. The GDD is used to quantify effect of temperature and describe the timing of different biological processes (McMaster and Wilhelm, 1997; Qiao-yun *et al*., 2012). The present study was conducted to quantify the relationship between GDD and phenological development of sesame.

A field experiment was carried out during two consecutive *kharif* seasons of 2010 and 2011 on sesame crop cv. 'RT 127' at the Research Farm of Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan (26.3°N latitude, 73.02°E longitude and altitude of 224 mean sea level). Average rainfall of the region is 368 mm, out of which about 90% is received during South West monsoon season between June to September. Soils of the experimental plots were originated from rhyolite and subsequently modified through alluvial and aeolian processes. Taxonomically, soils may be defined as coarse loamy mixed hyperthermic of camborthids. Soil organic carbon is very low (1.6 g kg^{-1}). Soil moisture contents at field capacity and at permanent wilting point were 9.5% and 3.0% (w/w), respectively. The crop was sown on 26th July 2010 and 18th July 2011 in sufficient soil moisture conditions. Seed rate at the time of sowing was maintained @ 2.5 kg ha^{-1}. All the agronomic

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practices and fertilizer application were performed as per standard recommendations.

Phenological development of crop with respect to GDD requirement was studied in 18 selected plants after emergence of leaves. Growth parameters such as plant height and number of leaves plant^{-1} were recorded at weekly interval during crop growing season. The weather parameters were collected from the meteorological observatory at CAZRI, Jodhpur. Growing degree days (GDD) were calculated from sowing to physiological maturity using the following equations:

$$\text{Accumulated GDD} = \sum\left[\frac{(T_{max}+T_{min})}{2}\right]-T_b \quad (1)$$

Where, T_{max} and T_{min} are daily maximum and minimum air temperature, respectively. T_b is the base temperature below which crop growth and development ceases. In case of sesame crop, T_b is 10°C.

Relationships between crop growth parameters and accumulated GDD were fitted using sigmoid growth curve as mentioned below:

$$y = \frac{a}{\left(1+\exp\left(-\frac{x-x0}{b}\right)\right)} \quad (2)$$

Where, y = plant height (cm) or number of leaves, x = accumulated GDD, a, b and $x0$ are parameters of sigmoid growth curve.

Sowing of crop was late (26 July) due to late onset of monsoon in the year 2010. However, it was sown timely (18 July) in the year 2011. The rainfall received during crop seasons 2010 and 2011 were 350.1 and 245.4 mm, respectively (Table 1). During both the years of study it was observed that maximum air temperature was slightly higher during crop season 2010 than 2011 whereas, minimum temperature was slightly higher in 2011 than 2010.

The GDD requirement for different phenological stages are shown in Table 2. It was observed that the accumulated GDD were 177 (°C-day) and 175 (°C-day) for emergence of first leaf during 2010 and 2011, respectively. For attaining flowering stage, higher accumulation of GDD (852 °C-day) was observed in 2011 as compared to 2010 (673 °C-day) crop season. Higher amount of GDD was also observed for physiological maturity in 2011 than 2010. The significant difference in GDD in the year of normal and late sowing year was also proportionately reflected at 50 and 100% flowering. However, GDD accumulation from initiation of flowering to 100% flowering was not differed (269-270 GDD) in both the years. This can be mainly attributed to difference in sowing time, where delayed sowing has reduced the GDD accumulation in vegetative period. The GDD requirement for early sown crop was observed to be more compared to late sown sunflower crop by Naresh Kumar (2005). It was also attributed to variations in GDD from emergence to head visible and emergence to first anther period but not due to photoperiod. Moreover, amount of rainfall during crop growth season in 2011 (245.4 mm) was less as compared to 2010 (350.1 mm). Langham *et al.* (2008) reported that availability of more moisture will shorten germination and seedling stages but will prolong vegetative and flowering stages. In our study also, germination and bud initiation required less GDD in 2010 due to higher amount of rainfall at the time of sowing and before bud initiation (Table 1). The results are in conformity with the findings of Pandey *et al.* (1990) under arid and semi-arid conditions of North Gujarat.

Table 1. Weather parameters during the crop growing season at Jodhpur

SMW	2010				2011			
	T_{min} (°C)	T_{max} (°C)	Rainfall (mm)	Bright sun shine hours	T_{min} (°C)	T_{max} (°C)	Rainfall (mm)	Bright sun shine hours
29	29.5	39.6	1.3	6.0	26.9	37.0	46.7	6.7
30	26.0	33.7	111.2	4.4	27.7	36.0	27.6	6.1
31	26.1	33.5	58.2	3.0	28.2	36.7	0.0	8.4
32	27.1	34.1	3.9	7.9	26.6	34.5	64	5.3
33	26.8	32.9	43.6	4.3	25.3	31.3	24.6	3.7
34	26.1	32.7	0.3	5.4	26.1	33.6	12.2	5.4
35	27.2	36.1	14.7	6.6	25.8	34.9	34.2	6.2
36	26.0	33.6	49.8	6.0	25.4	32.0	70	4.8
37	24.7	29.7	153.1	4.0	25.5	32.7	2.3	7.0
38	23.1	34.1	0.0	9.2	23.6	32.3	5.3	7.6
39	20.2	35.4	0.0	10.3	21.4	33.9	0.0	10.0
40	22.1	37.7	0.0	10.1	20.2	34.3	0.0	9.8
41	21.3	36.4	0.0	9.9	21.3	37.4	0.0	9.4

SMW = Standard meteorological weeks

Table 2. Accumulated GDD (°C- day) for different crop growth stages of sesame crop

Year	Germination	Leaves appearance		Bud initiation	Flowering				Physiological maturity
		1st	5th	1st	1st flower	25%	50%	100%	
2010	96	177	336	514	673	761	845	942	1572
2011	110	175	375	600	852	934	1031	1122	1580

It was observed that plant height increased with accumulation of GDD and attained a height of 124 cm after accumulation of about 1266°C-day GDD during 2010 crop season (Fig. 1a). Similarly, crop attained to a height of 132 cm after accumulation of 1240°C-day GDD during 2011 crop season (Fig. 1b). Sigmoid growth curve was found best to fit the experimental data in 2010 and 2011 (R^2=0.91 and R^2=0.88, respectively) (Table 3). Results revealed that 80 leaves plant^{-1} were observed after accumulation of GDD of 970°C-day during 2010 (Fig. 1c); whereas, 92 leaves were emerged in 2011 after receiving 1094°C-day unit of accumulated GDD (Fig. 1d). Sigmoid growth curve was found best to fit the experimental data in 2010 and 2011 (R^2=0.85 and R^2=0.62, respectively) (Table 3).

The GDD played an important role for crop growth and maturity rather than number of days after sowing. For example, average accumulated GDD of 1253 required for optimum plant height was received within 65 DAS in 2010; whereas, it was received after 62 DAS in 2011. The accumulated GDD of 514 required for initiation of first bud was received within 45 DAS in 2010; whereas, it was received after 27 DAS in 2011. For attending 100% flowering stage required accumulated GDD 942 and 1122 were received after 45 and 51 DAS in 2010 and 2011, respectively. Therefore, in the present context of shifting weather patterns including both rainfall and temperature change; there may be a requirement of new crop varieties considering the heat requirement for its physiological growth

Table 3. Fitting results of experimental data on crop growth parameters and GDD using sigmoid growth curve (eq. 3)

Growth parameters	Year	Sigmoid curve parameters			Results for best fit
		A	*b*	*x*0	(R^2)
Number of leaves plant^{-1}	2010	84.14	109.74	656.20	0.85
Number of leaves plant^{-1}	2011	104.39	158.88	799.71	0.62
Plant height (cm)	2010	125.44	143.52	733.25	0.91
Plant height (cm)	2011	135.28	133.43	776.01	0.88

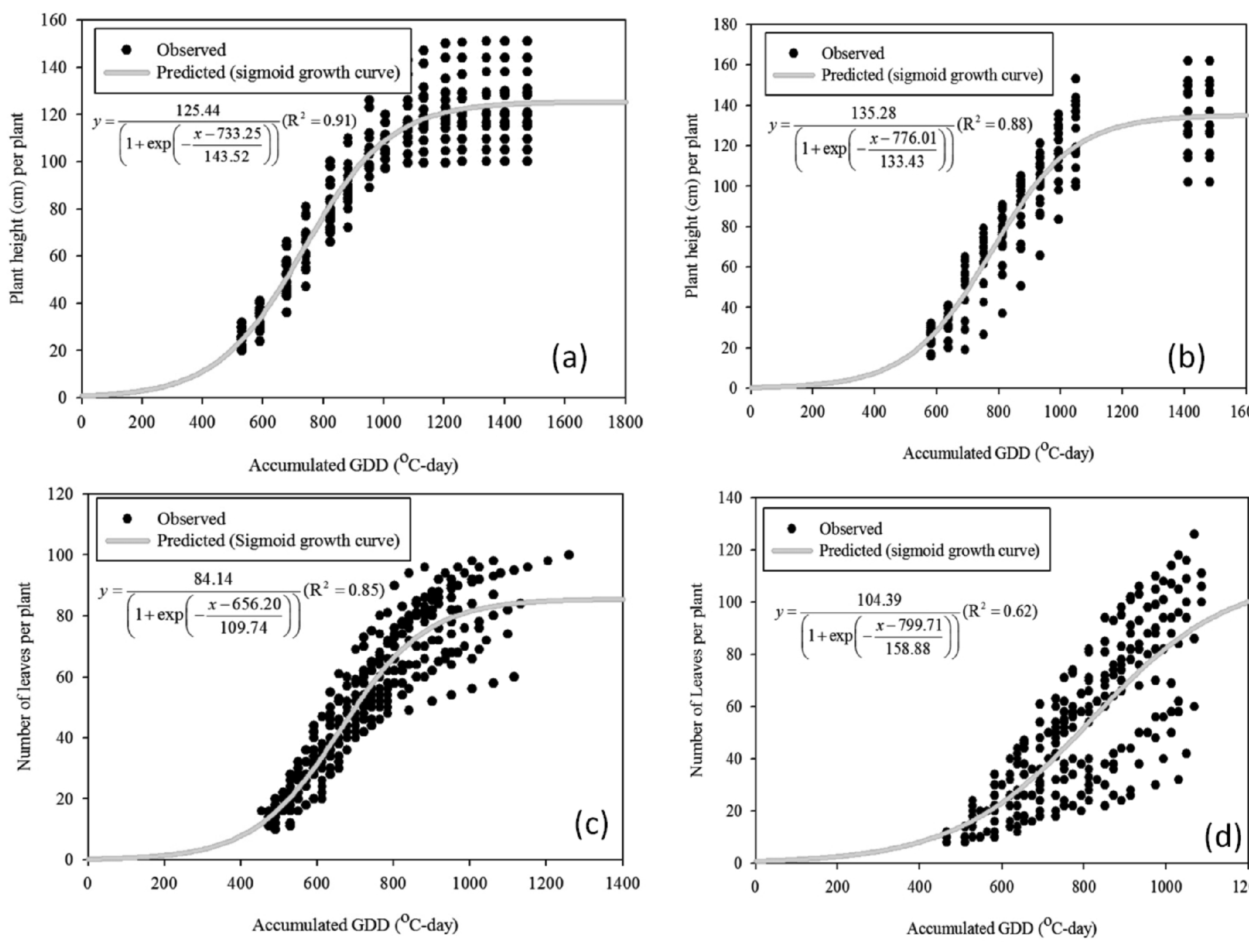

Fig. 1. Relationship between GDD and growth parameters of sesame crop during both the years of study. (a) plant height vs accumulated GDD in 2010, (b) plant height vs accumulated GDD in 2011, (c) number of leaves plant^{-1}vs accumulated GDD in 2010, and (d) number of leaves plant^{-1}vs accumulated GDD in 2011

and maturity. The relationship between GDD and crop growth of sesame developed in the study may help in the process of developing new crop varieties matching with shifting weather patterns.

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