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Summer sesame response to moisture and thermal regimes

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A field experiment was conducted at Instructional Farm of Soil and Water Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh during summer season (February - May) 2012 to study the sesame response to moisture and thermal regimes with three factorial strip plot design; three factors are thermal regimes (date of sowing), moisture regimes (Irrigation interval) and use of mulch. The crop was exposed to different thermal regimes at four different dates of sowing that is, 1st February, 14th February, 1st March and 14th March with different moisture regimes by varying the irrigation interval (3, 4 and 5 days irrigation interval). Results revealed that the seasonal depth of irrigation moreover decreased with delay in sowing from 1st February and the growing days requirement decreased with delaying sowing after 1st February with irrigation water depth 380, 402, 356 and 355 mm, while growing degree days as 109, 94, 83 and 74 days. The more number of growing days were required to mature the crop with less total thermal heat units as 2152, 1946, 1803 and 1722 degree - days, respectively. The sesame yield is significantly influenced by the thermal regimes. The highest and lowest sesame grain yield of 1131.59 and 555.20 kg/ha was observed for the thermal windows of 16th and 1st February, respectively. The grain yield increased rapidly by delaying the sowing from 1st to 21st February then it decreased slowly and continously. The vegetative stage was found the most sensitive stage to thermal regimes followed by establishment stage, flowering stage, ripening stage and reproductive stage. The highest grain yield of 991.27 kg/ha was found under drip irrigation at 3-days interval which was higher by the tune of 10.33, 17.32 and 20.86% as compared to that of under 4, 5 days under drip and 7-days under surface irrigation, respectively.

Key words: Sesame, thermal regimes, moisture regimes, drip irrigation in sesame, mulching in sesame.

INTRODUCTION

India occupies 329 M-ha geographical area, which is 2.4% of the world's land area; it supports over 15% of the world's population. The population of India on 31 March, 2011 was 1,210,193,422 persons. Thus, India supports (www.indianetzone.com). Drip irrigation is one of the best and latest methods for efficient utilization of irrigation

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water. It is an efficient method of application of water, in which the water is applied at low rate over longer period of time at frequent intervals with low-pressure delivery system, in order to avoid water stress to the plant. Drip irrigation provides high water use efficiency, higher crop yield, less labor requirement and relatively low operating cost, less weed growth, less insect and pest attacks, shorter growing season and earlier harvest of the crop. The soil moisture in the upper root zone is evacuated mainly due to soil evaporation and the water stored in the lower portion can be utilized efficiently by plants. To conserve water for a longer period and to reduce evaporation mulching is used. Mulching is the application of any plant residues or other materials to cover the top soil surface (Yadav, 2010).

Temperature is an important weather parameter that affects plant growth, development and yield. Temperature and radiation influence the rate of photosynthesis. However, plants also have an obligatory development in time, which must be met if the photosynthetic assimilates are to be converted into economically useful yields of satisfactory quantity and quality temperature and day-length in case of photosensitive crops influences the developmental sequence of crop growth in relation to crop phonology. Evolutionary changes that have occurred in the biochemical and physical characteristics of photosynthesis have resulted in a large variation between crops in both their optimum temperature requirements and the responses of photosynthesis to changes in temperature, radiation, and composition of the atmosphere. The objectives of this study were to: a) To assess the effect of thermal regimes during different growth stages of sesame crop on yield. b) To assess the effect of irrigation interval on crop yield.

MATERIALS AND METHODS

A field experiment was conducted at Instructional Farm of Soil and Water Engineering, CAET, JAU, Junagadh during summer season (February - May) 2012 to study the sesame response to moisture and thermal regimes with three factorial strip plot design. The experiment comprising of 24 treatment combinations were laid out in strip plot design with four replications. The treatment combination of four levels of thermal regime (four dates of sowing 1st February, 16th February, 1st March and 16th March, 2012) and three levels of irrigation interval viz. 3, 4, 5 days with drip irrigation and 7 days with surface irrigation without mulch as common to all treatments. Three factorial strip plots were used for the analysis of the data (Panse and Sukhatme, 1985).

First factor

Thermal window three levels
i) W_1 : 1st February
ii) W_2: 16th February
iii) W_3: 1st March
iv) W_4: 16th March

Second factor

Irrigation interval four levels
(i) I_1: 3 days by drip irrigation with mulch and without mulch (14 lph × 0.8 × 2.1 m)
(ii) I_2: 4 days by drip irrigation with mulch and without mulch (14 lph × 0.8 × 2.1 m)
(iii) I_3: 5 days by drip irrigation with mulch and without mulch (14 lph × 0.8 × 2.1 m)
(iv) I_4: Farmers practices (7 days by surface irrigation without mulch as control)

Third factor

Mulch level
i) With mulch
ii) Without mulch

There was season of no rainfall so elimination of rainfall depth and considered only the water required for the plant physiological growth and losses of water occurred by evaporatranspiration. During the course of study, there is no rain so the data regarding rain is meaningless to calculate The irrigation depth and time of application was decided based on the wetting the strip of 2.1 m. Irrigation was measured with water meter of 16 mm installed in the lateral of each treatment and calculated by the irrigation was applied at 3, 4 and 5 day interval under drip irrigation and at 7 days interval under surface irrigation as per treatments. Under drip system, the irrigation was continued till the wetted strips of 2.1 m (that is, 9 rows of sesame crop) was obtained. The time was noted to get 2.1 m wide wetted strip to cover 9 rows of the sesame crop. The dripper flow rate was measured and total flow volume of water was calculated. It was also verified with the 16 mm water meter fitted on lateral. The depth of irrigation applications was calculated using the following equation:

$$ID = V/A = q \times n \times t / A$$

Where, ID = depth of irrigation water application (mm); V = volume of water application in a treatment plot; q = dripper flow rate (lph); n = no of drippers in a treatment plot (nos.); A = area of the treatment plot (sq.m); t = time of irrigation application in respective treatment plot (hour).

Thermal heat unit calculated by daily maximum and minimum temperature were collected from the observatory and utilized for calculating the available heat units. The base temperature was taken as 15.56°C (Wanjura et al., 2002). The following expression was used to calculate the heat units:

$$HU = [T_{max} + T_{min}] / 2 - T_b$$

Where, HU is the heat units, degree-days/day; Tmax is the maximum temperature of the day, °C; and T_{min} is the minimum temperature of the day, °C and Tb is base temperature for sesame crop taken as 8°C (Ramankutty, 2002).

RESULTS AND DISCUSSION

Irrigation water applications

The seasonal depth of irrigation varied from 225 to 432 mm keeping irrigation interval of 5 days under thermal

Table 1. Seasonal depth of irrigation under different treatments.

Thermal window	Seasonal irrigation depth for Irrigation interval (days)						
	3		4		5		7
	M (mm)	NM (mm)	M (mm)	NM (mm)	M (mm)	NM (mm)	NM (mm)
01-Feb	405	405	396	396	346	346	488.8
16-Feb	432	432	330	330	303	303	454.8
01-Mar	376	376	309	309	280	280	390.4
16-Mar	300	300	237	237	225	225	320

M = Wheat straw mulch at 5 t/ha; NM = no mulch application.

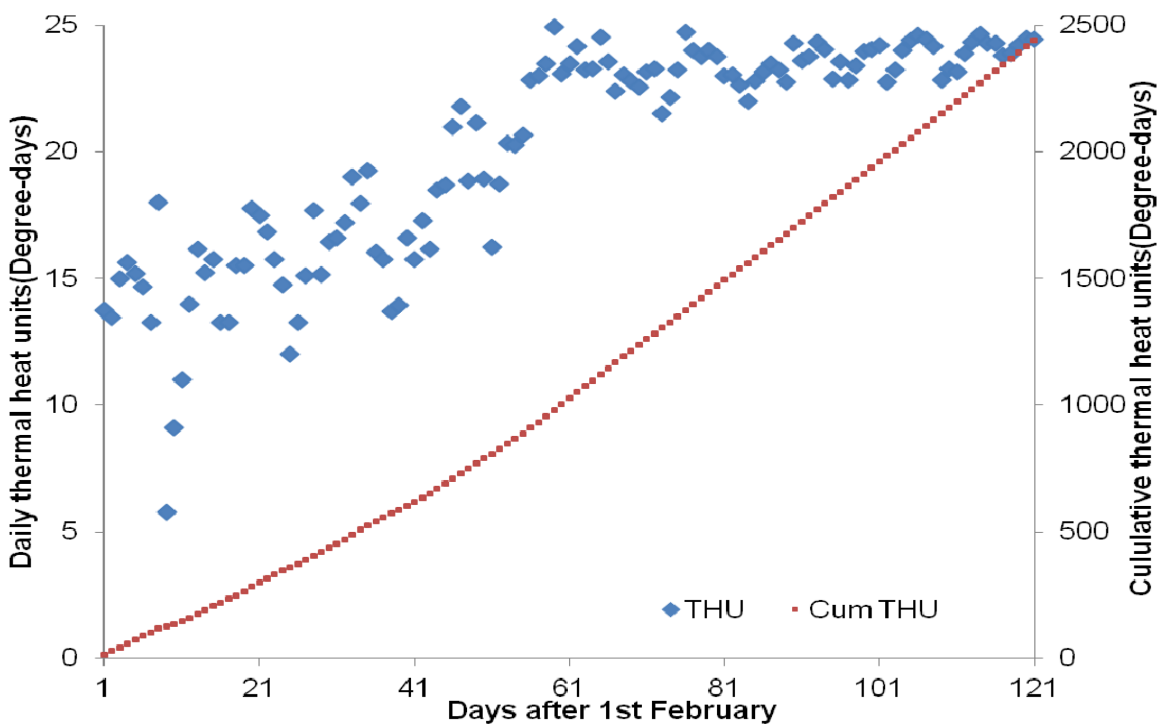

Figure 1. Daily and cumulative thermal heat units availability from 1st February.

window 16th March and 3 days irrigation interval under thermal windows of 16th February. The seasonal depth of irrigation applied under surface irrigation (7 days irrigation interval) varied from 488.8 to 320 mm under thermal windows of 16th March and 1st February. With delayed in sowing from 1st February the irrigation requirement of crop was found decreased, the reason behind that is decrease in number of growing days required for crop. As the heat unit availability increased the days required for maturity decreased with delay in sowing (Table 1 and Figure 1).

The highest growing days and inputs of seasonal thermal heat unit were found as 109 days and 2152 degree days, respectively for the thermal window - W1. The lowest growing days and inputs of seasonal thermal heat unit were found as 74 days and 1722 degree days for the thermal window - W1. As the seasonal thermal heat unit increased the growing days decreased the reason behind that is early maturity of the plant in higher thermal heat unit availability (Table 2 and Figure 2).

The estimated crop water requirements increased with delayed sowing from 1st to 16th February and then decreased. The reason behind increase in crop water requirement (that is, from 380 to 402 mm) up to thermal window of 16th February was due to increase in mean daily temperature and after 16th February decrease in crop water requirement was because of deceased in growing days requirements to mature the crop.

Table 2. Growing days, thermal heat unit inputs and average grain yield of sesame for different thermal windows.

Thermal window	Growing days	Seasonal thermal heat unit (degree-days)	Estimated water requirements as per climatic approach (mm)
01-February	109	2152	380
16- February	94	1946	402
01-March	83	1803	356
16- March	74	1722	355

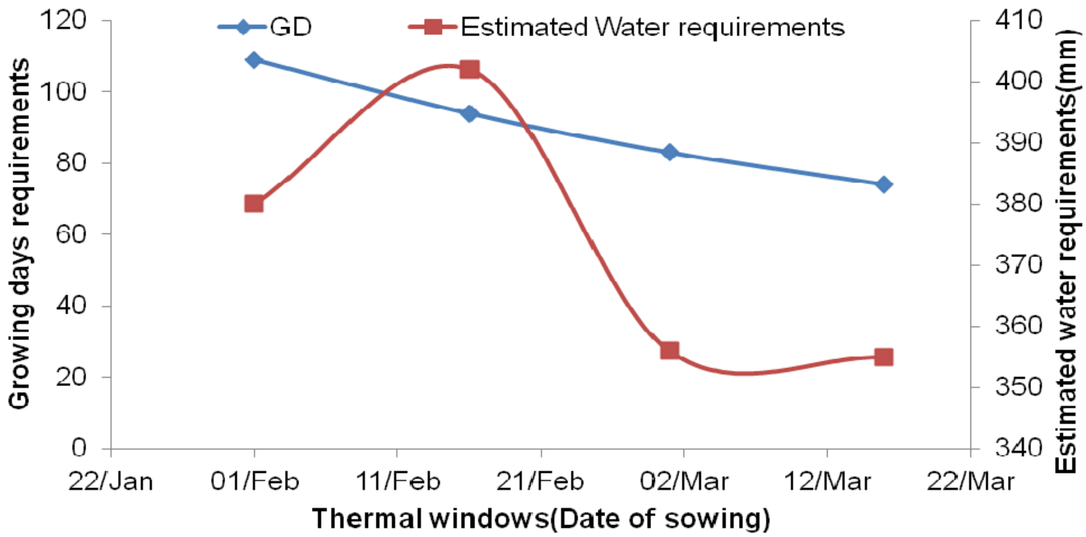

Figure 2. Effects of thermal windows on growing days and water requirements.

Effects of thermal regime on crop yield

The effects of seasonal thermal heat unit's availabilities on the sesame grain yield and thermal heat use efficiency is presented in Figure 3 and the grain yield obtained under different thermal window presented in Table 3. It was found that the highest and lowest sesame grain yield of 1131.59 and 555.20 kg/ha was observed for the thermal windows of 16th and 1st February, respectively. The thermal windows after 16th February resulted in decrease in crop yield. The pod yield 828.10 kg/ha was found under thermal windows of 16th March as the crop matured rapidly due to higher rate of thermal heat unit available per day. The highest grain yield under thermal windows of 16th February shows that the crop production can be optimum if the daily thermal heat units' availability is around 15, 18, 23 and 24 degree-days/day during the establishment, vegetative, flowering-reproductive and ripening stages, respectively. The crop yield decreased for the thermal windows later than 16th February. The pod yield of 828.10 kg/ha was found under thermal windows of 16th March as the crop matured rapidly due to higher rate of thermal heat unit availability per day. The highest grain yield under thermal windows of 16th February shows that the crop production can be optimum if the daily thermal heat units availability are around 15, 18, 23 and 24 degree-days/day during the establishment, vegetative, flowering-reproductive and ripening stages respectively. Sesame is generally a warm region plant and the temperatures recorded during this study were suitable for sesame growth and development. As per Cattan and Schilling (1991), temperature range of 25 to 27°C encourages rapid germination, initial growth and flower formation, whilst temperature below 18°C inhibit germination and growth (Ramankutty, 2001).

Crop yield response to thermal heat unit availability during growth stages

The crop yield response to thermal heat unit availability during growth stages are presented separately in Figures 4 and 5 for different irrigation interval with and without mulch. It could be seen that the quadratic relationship could be

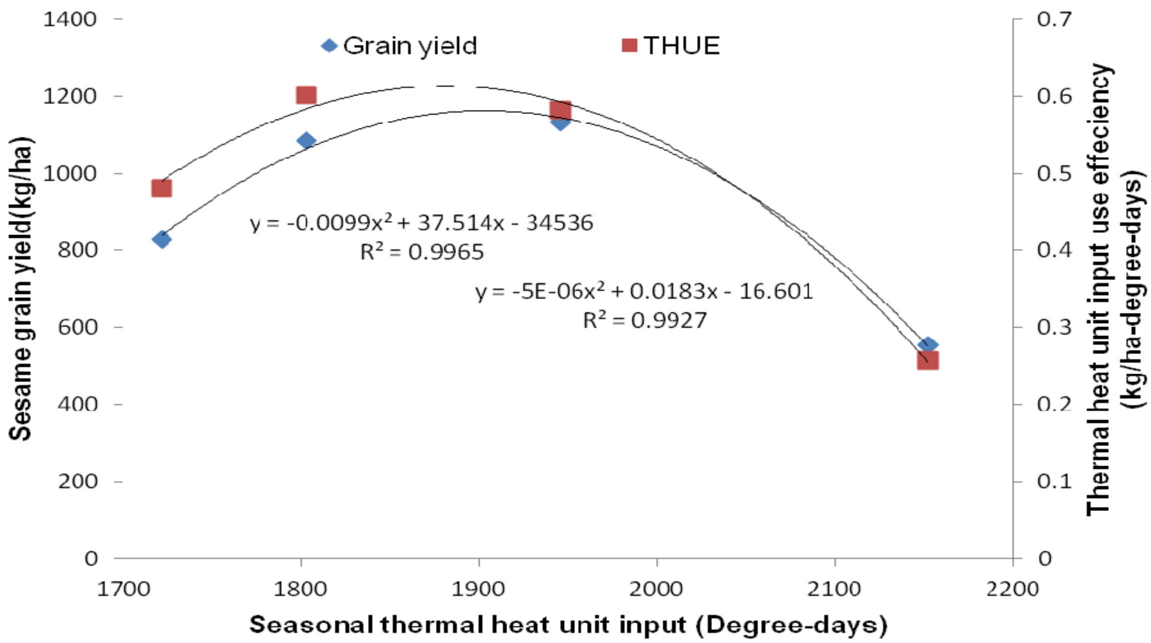

Figure 3. Effects of seasonal thermal heat units on sesame grain yield and thermal heat use efficiency.

Table 3. Effect of thermal window on grain yield of sesame.

Treatment	Grain yield (kg/ha)
Thermal window	
W_1 = 1st February	555.20
W_2 = 16th February	1131.59
W_3 = 1st March	1084.72
W_4 =16th March	828.09
SEm±	33.36
CD (0.05)	106.75
CV (%)	18.16

found between grain yield and thermal heat unit for all the stages. The yield decreased with increase in thermal heat unit availability up to certain level for establishment and vegetative stages. This indicated that these two stages require the lower thermal heat units. The reason behind the yield increase after reaching the minimum yield level could not be identified. It was found that the increase in thermal heat unit was due to increase in growing days requirement because of lower rate of thermal heat unit availability per day, which had slow down the physiological growth. The vegetative stage was found most sensitive followed by establishment stage, flowering stage, ripening stage and reproductive stage. The growth stages of sesame affected by the thermal heat availability and this result was contradictory with the result obtained by Tadashi et al. (2008) and Michiyama et al. (2005) for the flowering stage of sesame stating that low temperature during the flowering period decreased the rate of increase in the flowering-node number, although it prolonged the flowering period. Increased degree days over normal will shorten the vegetative and reproductive stages reported by Langham (2007).

Crop response to seasonal depth of irrigation

Crop yield response to seasonal depth of irrigation under different thermal window with mulch and no mulch is represented in the Figure 6. The linear relationship was found between grain yield and seasonal depth of irrigation for all the thermal windows. The yield decreased by reducing seasonal depth of irrigation and water applied

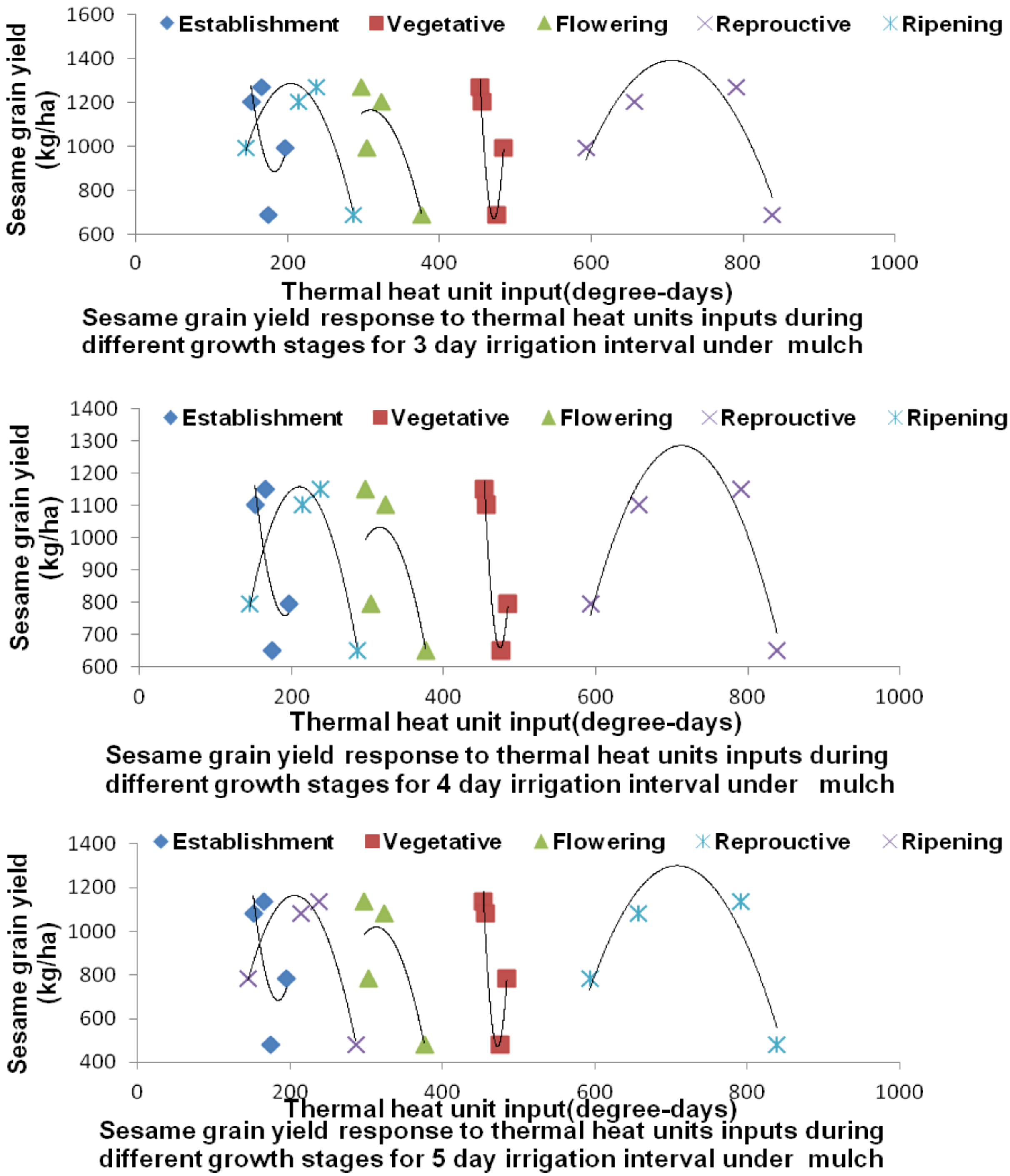

Figure 4. Sesame grain yield response to thermal heat units' inputs during different growth stages for 3, 4 and 5 days irrigation interval with mulch.

was lower than the optimal water requirements and yet there is a scope to enhance yield by increasing water application. The similar results obtained by Ucan (2007) who reported that the amount of irrigation water applied significantly affected the seed yield of sesame. Significantly higher grain yield was recorded in the treatments with higher water quantities treatments. The results obtained shows close agreement with the results of Foroud et al.

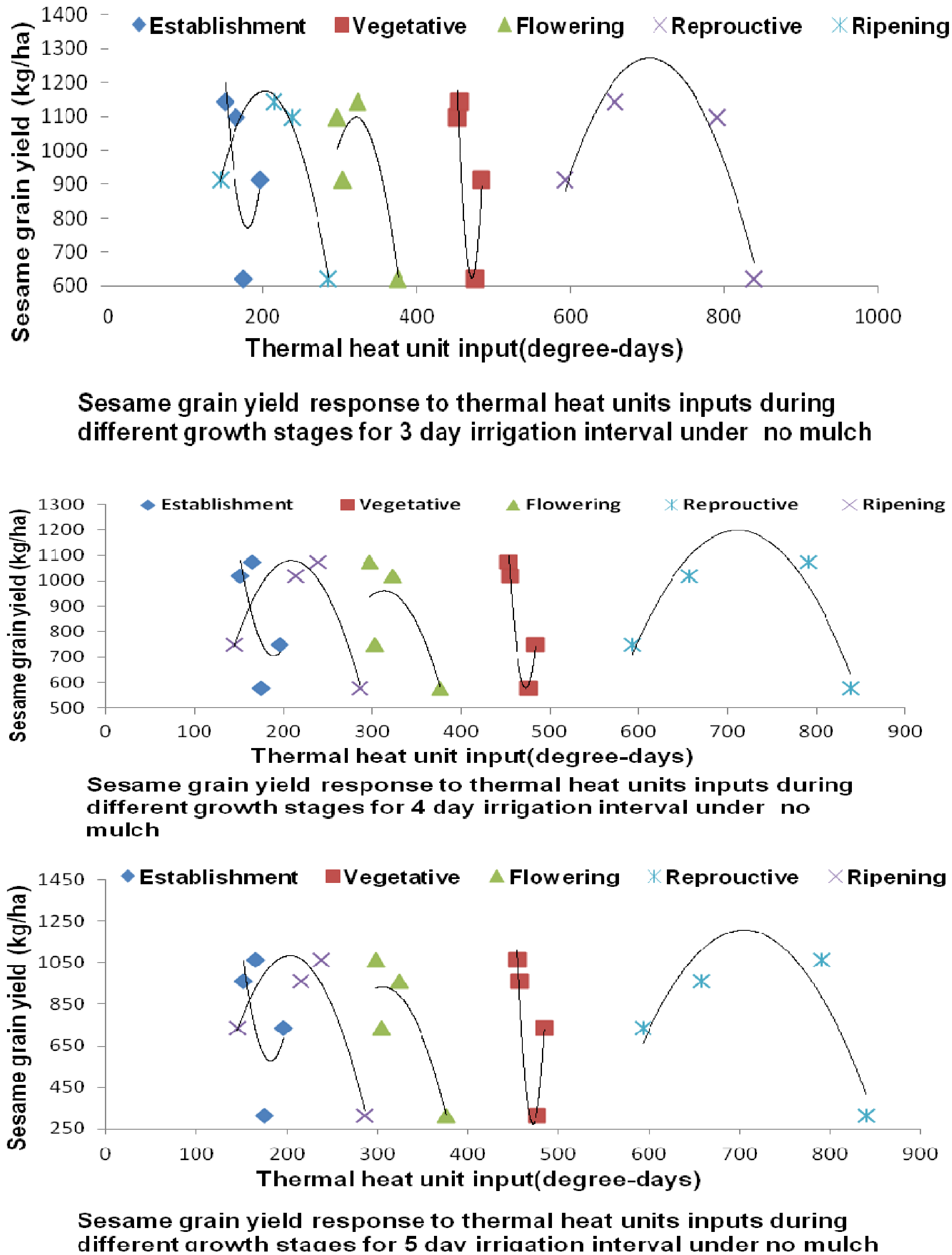

Figure 5. Sesame grain yield response to thermal heat unit's inputs during different growth stages for 3, 4 and 5 days irrigation interval under no mulch.

(1993) and Balasubramaniyan et al. (1996), who found that increase in yield was directly related to increased number of irrigations (Table 4).

Conclusions

Based on the data observations, analysis and its

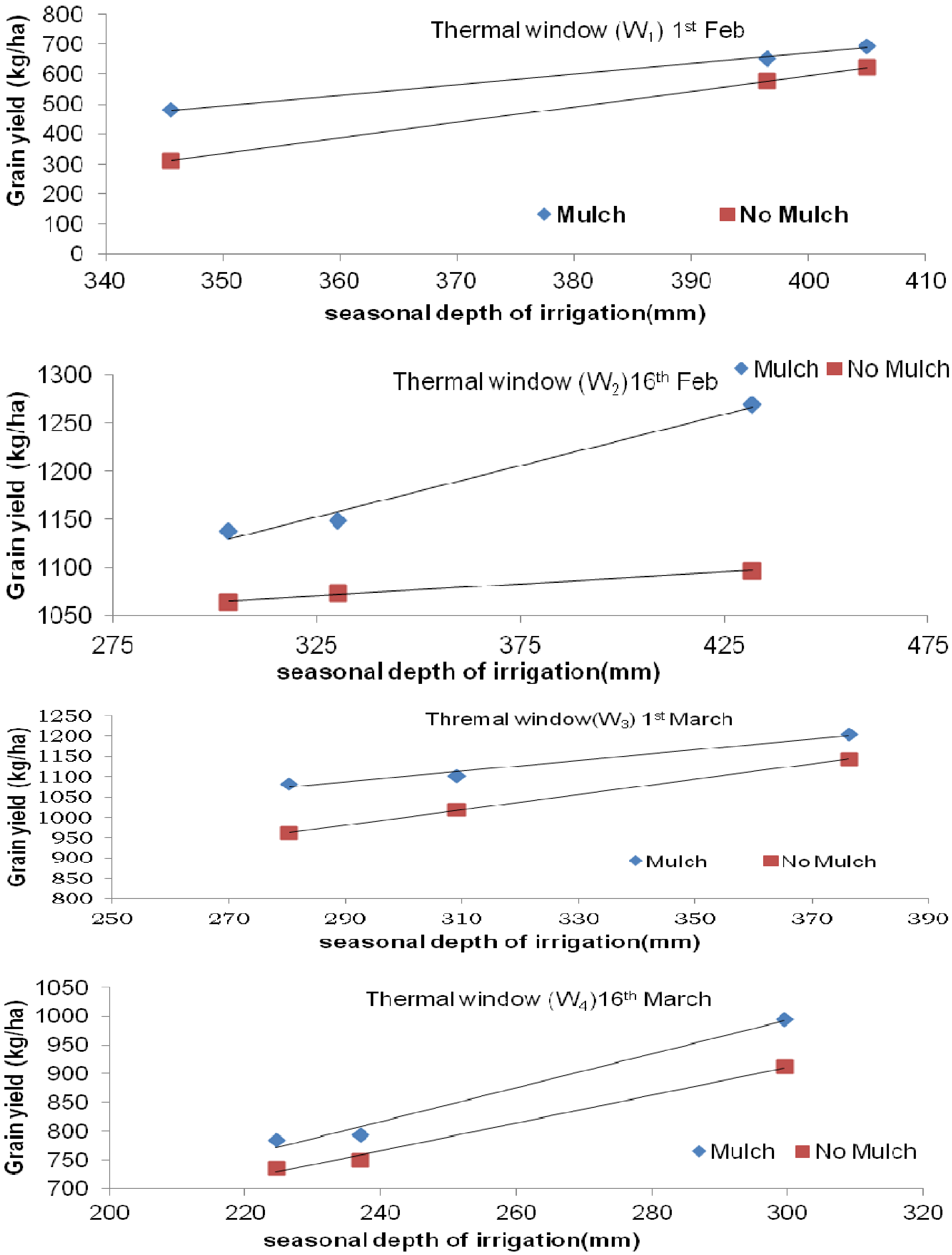

Figure 6. Sesame grain yield response to thermal heat units inputs during different growth stages for 3, 4 and 5 days irrigation interval with mulch.

interpretations, the following conclusions could be drawn from the present investigation:

1) The daily thermal heat units' availability was lower than 20 degree-days up to 45 days that is, 15th March, 2012. During

Table 4. Effect of Irrigation Interval on grain yield of sesame.

Irrigation interval	Grain yield (kg/ha)
I_1 = 3 days	991.27
I_2 = 4 days	888.86
I_3 = 5 days	819.56
Control = surface at 7 days	784.46
SEm. ±	31.92
CD (0.05)	110.47
CV (%)	20.06

45 to 75 days after 1st February, it varied from 20 to 23, while it was around 24 after that.

2) The highest daily thermal heat unit availability was 24.95 at 59th day after 1st February. The cumulative thermal heat unit of 2440 degree-days was observed after 121 days after 1st February.

3) The highest growing days requirements was observed as 109 days for 1st February (W1) with highest seasonal thermal heat unit for 109 days of 2152 degree-days while the lowest growing days requirements was observed as 76 days for the sesame sown at 16th March (W4) with lowest thermal heat units of 1722 degree-days.

4) If daily thermal heat unit availability is lower, the more number of growing days are required to mature the crop with less total thermal heat unit requirements.

5) The highest and lowest sesame grain yield of 1131.59 kg/ha and 555.20 kg/ha was observed for the thermal windows of 16th and 1st February, respectively it shows that the crop production can be optimum if the daily thermal heat units availability are around 15, 18, 23 and 24 degree-days/day during the establishment, vegetative, pod development and pod maturity stages respectively.

6) The grain yield observed under different irrigation interval with statistical analysis result shows the irrigation interval (I) had significant effect on grain yield of sesame. The highest grain yield of 991.27 kg/ha was found under irrigation by drip at 3-days interval which was higher by the tune of 10.33, 17.32 and 20.86% as compared to that of under 4, 5 days under drip and 7-days under surface irrigation respectively.

Conflict of Interests

The authors have not declared any conflict of interests.

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