Effect of thermal indices on yield of garlic (*Allium sativum* L.) varieties under variable weather conditions of South Saurastra Agro-climatic zone of Gujarat, India

ABSTRACT

A field experiment was conducted during Rabi (spring) season of year 2017-2018 at Junagadh Agricultural University, Junagadh, Gujarat, India. Four varieties of Garlic (GG-4, GJG-5, Promising and Local variety) were sown on four different dates for generating different weather condition during various phenological stages of crop. Results revealed that sowing between 7th to 21st November produced significantly higher growth due to fulfillment of optimum thermal requirement for various plant processes. Timely sown garlic crop recorded significantly higher GDD (growing degree days), HTU (helio-thermal units) and PTU (photo-thermal units) and HTU (Heat use efficiency). Delay in sowing (after 21st November) reduced the crop duration and yield. Yield had higher value in local variety followed by GG-4and GJG-5 in all weather conditions. Yield was more in timely sown crop as compared to late and very late sown crop. Local variety was found more conducive for growth and higher thermal unit.

Key words**:** Garlic, Heat use efficiency, Helio-thermal units, Phenophase, Thermal indices

INTRODUCTION

Garlic (*Allium sativum* L.) is an important bulb spice belonging to the family *Alliaceae* and the second most widely used cultivated bulb crops after onion. It is used both as a spice and vegetable. "It is rich in carbohydrates, proteins, phosphorous and ascorbic acid content. Garlic contains amino acid alliin, which is colourless and odourless. When cloves are crushed, due to enzymatic reaction of alliinase, allicin is converted into diallyl di sulphide gives true garlic odour" (Shankaracharya, 1974). "Garlic has several medicinal values. It reduces the cholesterol in the blood. Garlic juice is used in treatment of pulmonary tuberculosis, rheumatism, sterility, impotency, cough and red eyes" (Pruthi, 1979).

Growth and development of garlic are mainly affected by environmental conditions such as soil, photoperiod and temperature as well as agricultural practices, but temperature is a key factor for the timing of biological processes, and hence the growth and development of plants. Temperature also plays an important role in bulb initiation and formation in garlic. "Temperature variations have been shown to influence the rate of vegetative growth, leaf initiation, and emergence" (De Ruiter, 1986 and Tesfay *et al*., 2011). This study was conducted to study the effects of temperature in different planting date and cultivars on garlic vegetation parameter and yield.

MATERIALS AND METHODS

The field experiment was conducted during *Rabi* season of year 2017-2018 at Instructional Farm, Department of Agronomy, JAU, Junagadh, Gujarat, India. Geographically the experimental site was situated at 21.5222° N latitude and 70.4579° E longitude at an altitude of 107 m above mean sea level. The experiment was laid out in split plot design, consisting of 48 treatment combinations comprised of four sowing dates were 7th November (**D_1**), 14th November (**D_2**), 21st November (**D_3**) and 28th November (**D_4**) and four varieties were GG-4 (**V_1**), GJG-5 (**V_2**), Promising (**V_3**) and Local (**V_4**) with three replications. Observations were recorded at harvest time like plant height, girth and bulb yield. Meteorological observations are recorded on meteorological observatory near Instructional Farm.

Several Agrometeorological indices expressed as

Growing degree days can be mathematically expressed as

$$GDD = \sum_{ds}^{dp} [(T_{max} + T_{min})/2 - T_b]$$

Where, ds = Dates of sowing
dp = Dates of different phenological stages
T_{max} = Daily maximum temperature (°C)
T_{min} = Daily minimum temperature (°C)
T_b = Base temperature

The base temperature varies crop to crop and its value is derived from the growth behaviours of each and specific crop. Base temperature is the temperature below which plant growth is zero. Garlic crop base temperature is 5 °C, below this temperature growth cannot occur (El-Zohiri, 2014).

Photothermal unit formula given by Wang (1963)

PTU = GDD x N

Where, N = Maximum possible sunshine hours

Heliothermal unit formula

HTU = GDD x n

Where, n = Actual duration of bright sunshine hours

Heat use efficiency

$$HUE = \frac{\text{Total bulb yield (kg/ha)}}{\text{Accumulated GDD (degree days)}}$$

Data were subjected to analysis of variance (ANOVA) in a split-plot design as per the standard procedure.

RESULTS AND DISCUSSION

Effect of sowing dates:

Thermal indices during different phenophases

"First date of sowing (7th November) has a highest thermal indices like GDD, PTU and HTU in all the phenophases and lowest was observed in last date of sowing (28th November) (Table 1). All the phenophases had the highest thermal indices in first date of sowing. The maximum GDD to reach maturity was recorded on 7th November followed by other date of sowing which indicated that the crop exposed sub-optimal thermal regime with delay in sowing" (Agrawal *et al.*, 2002). Heliothermal and photothermal unit was recorded highest in 7th November followed by 14th November due to higher growing degree days (Hundal *et al.*, 2005) "while lowest value was recorded at 28th November. Bulb formation stage have highest thermal indices compare to the other phenophases because bulb formation stage have more growth days compare to other phenophases".

"First date of sowing had a days to taken for maturity was 130 days. Less days (109 days) to taken for maturity was observed in last date of sowing. First date of sowing had a highest cumulative growing degree day but second date of sowing had a highest bulb yield, so that heat use efficiency was observed highest (2.94 kg/ha °C day) in second date of sowing followed by first date of sowing (2.74 kg/ha °C day). Lowest heat use efficiency (2.51kg/ha °C day) was observed in last date of sowing. The heat use efficiency of the crop was reduced subsequently as the advancement of date of sowing. This indicates that the crop gets exposed to sub optimal thermal regime with delay in sowing. These results are in conformity with the findings" of Kulwinder *et al.* (2014) and Mohammad *et al.* (2018).

Yield and yield attributes

Different sowing dates brought significant influence on bulb yield. Highest bulb yield of 6205 kg/ha was recorded, when sowing done on 14th November followed by bulb yield (5910 kg/ha) on 7th November. The lowest bulb yield was obtained on 28th November due to poor partitioning of photosynthates from source to sink. Lower temperature, during vegetative and bulb formation phase were found more favorable for crop growth in between 7th to 21st November sowing. "Early planting gave higher yield due to the large size production of bulb. Delay planting significantly reduced the number of cloves and clove size. This may be due to the fact that plant did not receive a long cool growing period which was essential for the development of the bulb" as stated by Rahim (1988).

Table 1: Accumulated thermal indices during different phenophases of garlic as affected by various treatments

Treatments	Thermal indices	Germination phase	Vegetative phase	Bulb formation phase	Maturity phase
Sowing dates					
7th November (D$_1$)	GDD	262	587	723	590
	PTU	2920	6452	7967	6799
	HTU	2173	3572	5488	5043
14th November (D$_2$)	GDD	240	575	719	576
	PTU	2684	6254	7571	5902
	HTU	1980	3219	5219	4958
21st November (D$_3$)	GDD	237	546	684	538
	PTU	2625	5949	7284	5690
	HTU	1896	3203	5013	4756
28th November (D$_4$)	GDD	229	540	644	479
	PTU	2500	5898	6967	5397
	HTU	996	3688	4833	4561
Varieties					
GG-4 (V$_1$)	GDD	246	557	690	547
	PTU	2733	6089	7469	5992
	HTU	1778	3370	5242	4874

GJG-5 (V_2)	GDD	209	547	691	523
	PTU	2322	5956	7380	5783
	HTU	1566	3326	5017	4664
Promising (V_3)	GDD	228	559	686	546
	PTU	2531	6108	7392	5882
	HTU	1690	3380	5115	4765
Local (V_4)	GDD	284	585	704	567
	PTU	3142	6400	7548	6130
	HTU	2003	3606	5180	5015

Table 2: Heat use efficiency of garlic cultivars under different sowing dates

Sowing date and variety	Days taken	CGDD (°C day)	bulb yield (kg/ha)	HUE (kg/ha °C day)
D_1	130	2160	5910	2.74
D_2	123	2110	6205	2.94
D_3	116	2003	5340	2.67
D_4	109	1893	4769	2.51
V_1	120	2041	5694	2.79
V_2	112	1969	5288	2.69
V_3	116	2018	5050	2.50
V_4	125	2138	6191	2.90

Effect of varieties:

Thermal indices during different phenophases

Garlic variety significantly showed the result of date of sowing. All the thermal indices like GDD, PTU and HTU highest in all the phenophases in Local variety and lowest was observed in Promising variety (Table 1). All the phenophases had a highest thermal indices in Local variety. The maximum GDD to reach maturity was recorded in Local variety. Heliothermal and photothermal unit was recorded highest in local variety, while lowest value was observed in Promising variety. In local variety bulb formation stage has a highest thermal indices compare to the other phenophases because bulb formation stage have more growth days compare to other phenophases.

Local variety had days to taken for maturity was 125 days. Less days (116 days) to taken for maturity was observed Promising variety. Local variety had a highest cumulative growing degree days and highest bulb yield, so that heat use efficiency was observed highest (2.90 kg/ha °C day). Lowest heat use efficiency (2.50 kg/ha °C day) was observed in Promising variety.

Yield and yield attributes

Garlic bulb yield was affected significantly due to different varieties (Table 2). Significantly higher bulb yield (6191 kg/ha) was recorded in Local variety followed by GG-4 (5694 kg/ha) due to better growth and development. Lowest bulb yield (5050 kg/ha) observed Promising variety. Conclusively, sowing between 7th to 21st November gave significantly higher growth and yield observed in local variety compared to other.

CONCLUSION

Garlic crop growth and Bulb yield were relatively higher in the timely sown crop because of more congenial weather conditions during the entire crop growth period. Crop sown between 7th to 21st November recorded significantly more growing degree days, photothermal units, heliothermal units and heat use efficiency to attain maturity along with higher bulb yield of garlic crop as compared to late sown after 21st November. Bulb yield therefore could be optimized by doing appropriate management practices during different phenological stages for obtaining favourable weather condition for crop growth. Among different garlic varieties, Local and GG-4 variety were found to be the most suitable for higher productivity of garlic under agro-climatic condition of Junagadh (Gujarat).

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