Influence of growing environments on growth, phenology and fruit yield of tomato in semi-arid climate of Anand district of middle Gujarat region

Abstract

The investigation was carried out to study the influence of growing environment on growth, phenology and fruit yield of tomato at Agronomy farm, B. A. College of Agriculture, AAU, Anand, Gujarat (India) during *kharif* 2018-19 and *kharif* 2019-20 year. The objective was study of crop weather relationship in tomato. The treatment combinations consisting of three planting dates in main plot and three varieties in sub-plot were tested under split plot design with four replications. Three planting dates included D_1-1st August, D_2-15th August and D_3-10th August and three varieties included V_1- Arka Rakshak (Hybrid), V_2- Anand Tomato-3 and V_3- Gujarat Anand Tomato-5 during *kharif* year 2018-19 and year 2019-2020. During the year 2018-19, highest fruit yield (41.7 t ha^{-1}) was produced under 30th August planting and it was statistically at par with 15th August planting (38.8 t ha^{-1}) and lowest fruit yield was recorded in 1st August planting (35.6 t ha^{-1}). In the year 2019-20, similar trends were observed with slight low fruit yield in comparison to 2018-19. Similarly, in pooled results, significantly higher fruit yield was harvested under 30th August planting (40.7 t ha^{-1}) and it was statistically at par with 15th August planting (37.8 t ha^{-1}). Lowest fruit yield was recorded in 1st August planting (34.6 t ha^{-1}). A similar results pattern were found in yield attributing characters viz, plant height, fruit set percent, yield per plant and fruit weight, yield and yield attributes were found to increase with delayed planting (D_3- 30th August). Higher Heliothermal Unit (HTU) accumulated under 30th August planting followed by 15th August planting and 1st August planting. Higher HTU accumulated during year 2018-19 compared to year 2019-20. Correlation study showed that weather parameters had significant associations with dry matter during different phases and fruit yield of tomato. Result revealed that maximum temperature, minimum temperature and mean temperature were in the ranges of 30°C to 33°C, 13°C to 16°C and 23°C to 25 °C, respectively during fruit set stage under growing environment started with planting on 30th August which might be responsible for higher yield of tomato as compared growing environment started earlier for tomato crop.

Key word: Crop-weather relationship, Planting, GDD, PTU, HTU, Fruit yield, Biomass

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to family solanaceae and is one of the most important fruit vegetable crops widely grown throughout the world. In India, tomato is grown in 8.82 lakh hectares of land with production of 18227 metric tonnes (NHB, 2017). It is mainly grown in the states like Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh, Assam and Gujarat. In Gujarat, tomato is grown in 46 thousand hectares of land with production of 1156 metric tonnes (NHB, 2017). The tomato is a warm-season crop, it requires warm and cool climate. The plants cannot withstand frost and high humidity. Temperature and light intensity affect the fruit-set, pigmentation and nutritive value of the fruit. Long dry spell and heavy rainfall both shows detrimental effect on growth and fruiting. Temperature below 10°C and above 38°C adversely affects the plant tissues thereby slowdown physiological activities. It thrives well in temperature between 10°C to 30°C with optimum range of 21-24°C. The mean temperature below 16°C and above 27°C arenot desirable (Adams and Cockshull, 2001). For optimum growth and fruit setting, tomato requires 25–30°C day and 15–20°C night air temperature (Dhaliwal, 2012) and a root zone temperature (RZT) of 25.4–26.3°C (Díaz-Pérez and Batal, 2002). Avoid water stress and long dry period as it causes cracking of fruits. Bright sunshine at the time of fruit set helps to develop dark red colored fruits. Crop yield is affected by many factors, primarily encompassing soil and weather conditions, and crop management practices. Final yield of any crop is manifestation of all environmental factors that affected growth and development during life cycle of the crop. Weather variability is considered one of the major factors of inter-annual variability of crop growth and yield in all environments. Besides, rainfall, temperature and bright sun shine hours also have been bearing on crop growth and development as well as yield response of different species to different environments, can be quite different. Shift in transplanting dates (growing environments) directly influences both thermo and photoperiod and consequently have great impact on the phasic development and partitioning of dry matter. Quantification of these effects may help in the choice of transplanting time and match phenology of crop in specific environment to achieve higher crop yield.

Therefore the experiment was carried out with objective of study of crop weather relationship of tomato at Anand district of middle Gujarat, India.

2. METHODOLOGY

The field experiments were conducted at agronomy research farm (Plot number A/24 Plot), Anand Agricultural University, Anand (Gujarat), India. Geographically, the site is located at 22°35' N latitude and 72°55'E longitude and at an altitude of 45.1 m above mean sea level. The location of the experimental site falls under the middle Gujarat agro-climatic zone-III. Climate of this location has been classified as semi-arid tropical with fairly hot and dry summer with mild winter. The experimental plot has loamy sand soil, which is locally known as “Goradu” soil. This soil is of alluvial origin and belongs to Entisols (Type: Ustorthents). Neutral in reaction, low in available nitrogen, phosphorus and high in available potassium. The experimental field has a good drainage as well as fair moisture retentive capacity. Tomato crop was transplanted at three planting dates vizm D_1-1st August, D_2-15th August and D_3-10th August as a main plot and three varieties included V_1- Arka Rakshak (Hybrid), V_2- Anand Tomato-3 and V_3- Gujarat Anand Tomato-5 as a subplot with four replications during *kharif* year 2018-19 and year 2019-2020. 30 day old seedlings were transplanted to the experimental field with planting spacing of 75 x 45 cm. A recommended fertilizer dose of i.e. 125:50:50 kg was applied in split doses as per AAU package of practices. Other cultural operations and plant protection measures were followed as per the recommendation.

The weather data during experimental period was recorded from the meteorological observatory located at Department of Agricultural Meteorology, B. A. College of Agriculture, AAU, Anand, Gujarat. The total crop growth period of tomato was devided into four phenophases such as transplanting to first flower (P1 stage), First flower to fruit initiation (P2 stage), Fruit initiation to first picking (P3 stage) and first picking to last picking (P4 stage) as suggested by Mutkule *et al*., (2018). Phenophase wise weather parameters like maximum temperature, minimum temperature, mean temperature, morning relative humidity, afternoon relative humidity, rainfall, sunshine hours were calculated and depicted in Fig 1. Correlation coefficient was worked out for association between weather parameters and fruit

yield and dry matter and yield attributing characters during different phenophases of tomato.

3. RESULTS AND DISCUSSION

Yield and Yield attributes

Fruit set percent

The data of percent fruit set of tomato as influenced by growing environments individual year as well as pooled statistical results of percent fruit set are presented in Table 1. Results showed that fruit set percent was significant during both years due to different dates of plantingas well as in pooled results. Significantly highfruit set percent (55.33 % and 53.60 %) was recorded under D_3 planting.D_1 planting recorded significantly lowest fruit set percent (49.39 % and 46.44 %) it was at par with D_2 planting. Fruit set percentage was more during 2018-19 as compared to 2019-20. Crop planted under D_3 encountered optimum thermal condition for higher fruit set percent.

Pooled results showed similar type of results under different dates of planting. Highest fruit set percent (54.47 %) was recorded under D_3 planting. Significantly lowest average fruit weight (47.91 %) was recorded under D_1 planting.

From the above results, it was concluded that significantly highest fruit set percent was recorded under D_3 and D_2 plantings. This suggests that D_2 and D_3 planting dates were found most optimum for higher fruit set percent of tomato under middle Gujarat region.

Average fruit weight

The data of average fruit weight (g) of tomato as influenced by growing environments and varieties is given in Table.2

Results showed that average fruit weight was significant during both years due to different dates of planting. Significantly highest average fruit weight (65.76 g and 63.79 g) was recorded under D_3 planting and it was at par with D_2 planting. D_1 planting recorded significantly lowest average fruit weight (59.41 g and 57.04 g)Fruit weight was more during 2018-19 as compared to 2019-20. Pooled results showed similar type of results under different dates of planting. Highest average fruit weight

(64.79 g) was recorded under D_3 planting and it was at par with D_2 planting, whereas lowest average fruit weight (58.22 g) was recorded under D_1 planting.

From the above results, it was concluded that significantly high average fruit weight were achieved under D_3 and D_2 plantings. This suggests that D_2 and D_3 planting dates were optimum for higher fruit weight of tomato under middle Gujarat region.

Fruit yield per plant

The fruit yield per plant (kg plant^{-1}) of tomato as influenced by growing environments Results showed that fruit yield per plant were significant during both years due to different dates of planting. Significantly highest fruit yield per plant (2.33 kg plant^{-1} and 2.24 kg plant^{-1}) was recorded under D_3 planting. D_1 planting recorded significantly low fruit yield per plant (2.02 kg plant^{-1} and 1.88 kg plant^{-1}) it was at par with D_2 planting. Fruit yield per plant was more during year 2018-19 as compared to year 2019-20. Higher fruit yield per plant due to favorable thermal regime during first year.

Pooled results showed similar type of results under different dates of planting. Highest fruit yield per plant (2.28 kg plant^{-1}) was recorded under D_3 planting.Lowest fruit yield per plant (1.95 kg plant^{-1}) was recorded under D_1 planting.

From the results, it was concluded that significantly highest fruit yield per plant were recorded under D_3 and D_2 plantings. This suggests that D_2 and D_3 planting dates were optimum for high fruit yield per plant of tomato under middle Gujarat region.

Total fruit yield

The total fruit yield (t ha^{-1}) of tomato as influenced by growing environments and varieties are given in Table 4..Results showed that total fruit yield was significant during both years for dates of planting. Significantly high total fruit yield (41.71 t ha^{-1} and 39.75 t ha^{-1}) was recorded under D_3 planting, however it was at par with D_2 planting. D_1 planting recorded significantly lowest total fruit yield (35.60 t ha^{-1} and 33.64 t ha^{-1}). Total fruit yield was more during 2018-19 as compared to 2019-20. Total fruit yield remained in order of D_3>D_2>D_1 in both the years.

Pooled results showed similar type of results under different dates of planting. Highest total fruit yield (40.73 t ha^{-1}) was recorded under D_3 planting and it was at par with D_2 planting, whereas lowest total fruit yield (34.62 t ha^{-1}) was recorded under D_1 planting.

It was concluded that significantly high total fruit yield was recorded under D_3 and D_2 plantings. This suggests that D_2 and D_3 planting dates were found most optimum for higher total fruit yield of tomato.

Table 1.: Fruit set percentage of tomato as influenced by growing environments and varieties

Treatment	Fruit set (%)		
	2018-19	2019-20	Pooled
Main Plot treatment (Date of planting)			
D_1 (1st August)	49.39	46.44	47.91
D_2 (15th August)	51.31	48.66	49.99
D_3 (30th August)	55.33	53.60	54.47
SEm±	1.02	1.59	0.94
CD at 5 %	3.52	5.50	2.91
CV %	6.77	11.1	9.10
Sub plot treatment (Varieties)			
V_1 (Arka Rakashak)	58.68	56.04	57.36
V_2 (AT-3)	47.93	45.21	46.57
V_3 (GAT-5)	49.42	47.46	48.44
SEm±	0.92	1.42	0.86
CD at 5 %	2.73	4.23	2.43
CV %	6.11	9.92	8.15
Interactions	NS		

Table 2.: Fruit yield per plant of tomato as influenced by growing environments and varieties

Treatment	Fruit yield per plant (kg plant^{-1})		
	2018-19	2019-20	Pooled
Main Plot treatment (Date of planting)			
D_1 (1st August)	2.02	1.88	1.95
D_2 (15th August)	2.14	2.05	2.10
D_3 (30th August)	2.33	2.24	2.28
SEm±	0.05	0.06	0.05
CD at 5 %	0.18	0.17	0.13
CV %	8.34	10.01	9.18
Sub plot treatment (Varieties)			
V_1 (ArkaRakashak)	2.56	2.44	2.50
V_2 (AT-3)	1.83	1.74	1.78
V_3 (GAT-5)	2.11	1.99	2.05
SEm±	0.06	0.06	0.05
CD at 5 %	0.17	0.19	0.18
CV %	9.01	9.61	9.30
Interactions	DxV		

Table 3.: Fruit weight of tomato as influenced by growing environments and varieties

Treatment	Average fruit weight (g)		
	2018-19	2019-20	Pooled
Main Plot treatment (Date of planting)			
D_1 (1st August)	59.41	57.04	58.22
D_2 (15th August)	63.00	61.03	62.00
D_3 (30th August)	65.76	63.79	64.79
SEm±	1.34	1.35	1.34
CD at 5 %	4.64	4.65	2.93
CV %	7.41	7.67	7.55
Sub plot treatment (Varieties)			
V_1 (ArkaRakshak)	70.84	68.74	69.78
V_2 (AT-3)	55.27	53.16	54.22
V_3 (GAT-5)	62.07	59.96	61.02
SEm±	1.25	1.27	1.25
CD at 5 %	3.71	3.79	2.53
CV %	6.89	7.13	7.01
Interactions	NS		

Table 4.: Total fruit yield of tomato as influenced by growing environments and varieties

Treatment	Total fruit yield (t ha^{-1})		
	2018-19	**2019-20**	**Pooled**
Main Plot treatment (Date of planting)			
D_1 (1st August)	35.60	33.64	34.62
D_2 (15th August)	38.83	36.87	37.85
D_3 (30th August)	41.71	39.75	40.73
SEm±	1.34	1.36	1.35
CD at 5 %	4.61	4.68	2.97
CV %	11.93	12.56	12.24
Sub plot treatment (Varieties)			
V_1 (ArkaRakashak)	43.95	41.99	42.96
V_2 (AT-3)	33.57	31.61	32.59
V_3 (GAT-5)	38.63	36.67	37.65
S.Em.±	0.76	0.79	0.78
CD at 5 %	2.26	2.28	1.57
CV %	6.81	7.17	6.98
Interactions	NS		

4.5.4 Total fruit yield

The total fruit yield (t ha-1) of tomato as influenced by growing environments and varieties are given in Table 4.Results showed that total fruit yield was significant during both years for dates of planting. Significantly high total fruit yield (41.71 t ha-1 and 39.75 t ha-1) was recorded under D3planting, however it was at par with D2 planting. D1 planting recorded significantly lowest total fruit yield (35.60 t ha-1 and 33.64 t ha-1). Total fruit yield was more during 2018-19 as compared to 2019-20. Total fruit yield remained in order of D3>D2>D1 in both the years.

Pooled results showed similar type of results under different dates of planting. Highest total fruit yield (40.73 t ha-1) was recorded under D3 planting and it was at par with D2 planting, whereas lowest total fruit yield (34.62 t ha-1) was recorded under D1 planting.

It was concluded that significantly high total fruit yield was recorded under D3 and D2 plantings. This suggests that D2 and D3 planting dates were found most optimum for higher total fruit yield of tomato.

Associations of weather parameters with dry matter yield and yield attributes

Crop productivity mainly depends upon prevailing weather condition during growing period. Correlation studies between weather parameters, dry matter production and fruit yield of tomato would help to understand the effect of weather parameters at various phenophases. Therefore correlation coefficient between weather parameters and dry matter production and fruit yield are given in Table 4.

Correlation coefficients studies between maximum temperature and dry matter production and fruit yield of tomato. Maximum temperature during P1 phase (transplanting to first flower) showed significant positive correlation with dry matter production. However maximum temperature during P3 phase (fruit initiation to first picking) was significant and negatively correlated with dry matter. Maximum temperature during P1 phase (transplanting to first flower) showed significant positive correlation with fruit yield. Sarada *et al*. (2015) also reported positive correlation between maximum temperature and fruit yield. The present experimental results revealed that during growing period, the maximum temperature range of 30.7 °C to 32.8 °C during P1 phase (transplanting to first flower) was favorable for fruit yield of tomato.

Minimum temperature during P3 phase (fruit initiation to first picking) was showed significant positive correlation with dry matter. However, dry matter production was significant and negatively correlated with minimum temperature during P4 phase (first picking to last picking).

Minimum temperature and yield attributes and fruit yield of tomato indicated that, mean minimum temperature during P3 phase (fruit initiation to first picking) showed significant positive correlation with fruit yield. However, during P4 (first picking to last picking) phase minimum temperature exerted significant negative

correlation with fruit yield of tomato.

Positive correlation was found between temperature during P1 stage (transplanting to first flower) with dry matter production. Mean temperature during P3 phase (fruit initiation to first picking) was significant positively correlated with dry matter production. However, mean temperature during P4 stage (first picking to last picking) was significant and negatively correlated with dry matter production.

Correlation studies between mean temperature and fruit yield of tomato showed positive correlation during P3 phase (fruit initiation to first picking). Mean temperature during P1 (transplanting to first flower) and P3 phases (fruit initiation to first picking) showed significant positive correlation with fruit yield.

Dry matter production showed significant positive correlation with morning RH during P_4 phase (first picking to last picking). However, morning RH during P_3 phase (fruit initiation to first picking) showed highly significant negative correlation with dry matter production.

Morning RH and fruit yield of tomato revealed that, morning RH during P_4 phase (first picking to last picking) had significant positive correlation. However, morning RH during P_3 phase (fruit initiation to first picking) was significant negatively correlated with fruit yield. Ajithkumar (1999) also reported significant negative correlation of morning RH with average fruit weight and fruit yield per plant.

Afternoon RH during P_2phase (first flower to fruit initiation) showed significant positive correlation with dry matter production. However afternoon RH during P_3phase (fruit initiation to first picking) showed significant negative correlation with dry matter production. Afternoon RH during P_2phase (first flower to fruit initiation) was positively correlated with fruit yield. During P_3 phase (fruit initiation to first picking) correlation between afternoon RH and tomato fruit yield was significantly negative.

Rainfall of P_3 phase (fruit initiation to first picking) had significant negative correlation with dry matter production. Jedrszczyk *et al*. (2012) reported decreased fruit yield of tomato with high rainfall.

Sunshine hours during P_4 phase (first picking to last picking) was negatively correlated with dry matter production. The correlation studies between sunshine hours and fruit yield of tomato revealed that, sunshine hours during P_4 phase (first

picking to last picking) had significant negative correlation with fruit yield.

Table. 5 Correlation coefficients between weather parameters during different phenophases and dry matter production and fruit yield of tomato

Growth phases	Maximum temperature	Maximum temperature	Mean temperature	Morning relative humidity	Afternoon relative humidity	Rainfall	Sunshine hours
Dry matter production							
Transplanting to first flower	0.52*	0.09	0.34	0.05	-0.22	0.34	0.06
First flower to fruit set	0.62**	0.17	0.45*	-0.005	-0.29	0.25	0.07
Fruit set to first picking	-0.64**	0.69**	0.52	-0.72**	-0.55**	-0.62*	0.41
First picking to last picking	-0.17	-0.68**	-0.62**	0.24*	0.21	-0.54*	-0.55*
Fruit yield							
Transplanting to first flower	0.65**	0.09	0.47*	0.05	-0.21	0.10	0.10
First flower to fruit set	-0.25	-0.07	-0.24	0.08	0.51*	-0.19	-0.19
Fruit set to first picking	-0.63**	0.71**	0.56*	-0.81**	-0.63**	0.34	0.34
First picking to last picking	-0.23	-0.82**	-0.71**	0.71**	0.19	-0.51*	-0.49*
*Significant at 5 % level; **Significant at 1 % level, n = 9							

4. CONCLUSION

Maximum temperature, minimum temperature and mean temperature were in the ranges of 30°C to 33°C, 13°C to 16°C and 23°C to 25 °C, respectively during fruit set stage under growing environment started with planting on 30th August which might be responsible for higher yield of tomato as compared growing environment started earlier for tomato crop.

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