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Effect of microclimate on growth and fruit yield of okra (*Abelmoschus esculentus*)

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ABSTRACT

A field experiment was conducted to study the effect of microclimate on growth and fruit yield of okra in March 2018. The main plot treatments consist of three date of sowing i.e. D1 - 1st week of March D2 - 2nd week of March, D3 - 3rd week of March and sub plot treatments consist of three varieties i.e. V1 - Varsha Uphar, V2 - Hisar Naveen and V3 - Hisar Unnat and two planting system i.e. P1: Furrow Irrigated Raised Bed Planting and P2: Flat Bed Planting. The eighteen treatment combinations were tested in split plot design with three replications. In the all three growing environment the leaf area index, dry matter accumulation, fruit yield and yield attributes were maximum with treatment D2 followed by D1 and D3 when crop was sown on 14th March followed by 6th March and 28th March. In case of okra varieties, Hisar Naveen produced the highest leaf area index (LAI), dry matter (DM) accumulation, fruit yield and yield attributes followed by Hisar Unnat and Varsha Uphar. Among the planting systems, the LAI, DM accumulation, fruit yield and yield attributes were maximum in furrow irrigated raised bed planting than that of flat bed planting system. The data on correlation between weather parameters and yield and yield attributes indicate that growth and yield of okra showed positive correlation with maximum and minimum temperature and negatively correlated with morning and evening relative humidity. Correlation between sunshine hours with yield and yield attributes was found to be non-significant.

Key Words: Growth, fruit yield, microclimate, okra

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench), an economic vegetable crop of tropical and sub-tropical regions of the world, locally known as Bhindi and is one of the major *kharif* and summer season cultivated vegetable crop of India as well as Haryana. It belongs to family, Malvaceae and has the typical floral characteristics of that family originating from Africa. India ranks first among the world with 6346 thousand metric tonnes (72 % of the total world production) in okra production (Anonymous, 2014). Haryana, which is one of the major okra growing states, produces 186.30 thousand metric tons of okra from 24.38 thousand hectares area with an average productivity of 7.9 metric tonnes ha^{-1} (Anonymous, 2014). There is a slight increase in area, production and productivity of okra in India from the year 2006-07 to 2013-14. Okra is cultivated for its fibrous fruit or pods containing round seeds. The fruits are harvested at immature and eaten as vegetable.Studies on crop microclimate can provide valuable information regarding the interaction of the crop with its environment. The sowing date and planting system are two most important variable belonging changes in microclimate and consequently growth and yield. Due to its susceptibility to yellow vein mosaic virus disease area under this crop is decreasing during the rainy season. It is well established fact that when the crops are grown during spring-summer season its fetches better returns to the farmers due to scarcity of the other green vegetables in the market during this season. A new technique of sowing named FIRBS i.e., Furrow Irrigated Raised Bed Planting System is form of conventional tillage wherein sowing is done on the raised beds. It is one of the important components of low cost sustainable production system. According to Ekwu and Nwokwu (2012) reported that the number and weight of fruits per plant as well as the number of the vegetative branches of okra per plant decreased significantly with increase in population density. Time of sowing is also one of the most important factors which govern the phenological development and total biomass production along with efficient conversion of biomass into economic yield. Soomro *et al.* (2000) observed the optimum time of sowing of crop from 5th to 20th May which gives highest yield as compared

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to early or late sown under Sakrand conditions. Further, Elhag and Ahmed (2014) studied the effect of three sowing dates i.e., 1st July, 20th July and 10th August on seed yield of two okra cultivars (Khartoumia and Wad Gammer) and the results showed that the best vegetative growth and yield were obtained at 1st July as compared to other dates of sowing. The effect of microclimate on vegetable has not been much studied in India. Consequently, it is difficult to guide the farmers regarding the agrometeorology aspects of this crop during summer season. Keeping this in view the above concerns, the present study was planned with objective to study the effect of microclimate on growth and fruit yield of okra.

MATERIALS AND METHODS

Experimental site and location:

The experiment was conducted at CCS Haryana Agricultural University, Hisar (latitude 29.10 ^{0}N, longitude 75.46 ^{0}E). It has an average elevation of 215 meter above mean sea level. Hisar is located in western part of Haryana on the outer margins of the South-west monsoon. The average annual rainfall is around 450 mm, and most of which occurs during the months of SW monsoon.

Climate and weather:

The climate of Hisar region owes to its continental location on the outer margins of the monsoon regioni.e.,1600 Kmaway from the ocean. It has arid subtropical monsoonal climate. From October to the end of June next, the weather remains extremely dry, except for a few light showers received due to western disturbances. About 80 per cent of annual precipitation is received in the south-west monsoon season (June to September). Summers are very hot (maximum temperature touches 45 ^{0}C or sometimes more) and winters are fairly cool (minimum temperature around 1 to 2 ^{0}C or sometimes less and may fall below 0^0 C).

Experimental details:

A field experiment was conducted at the research area of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, during summer season, 2013. The main plot treatments consist of three date of sowing i.e. D1 - 1st week of March D2 - 2nd week of March, D3 - 3rd week of March and sub plot treatments consist of three varieties i.e. V1 - Varsha Uphar, V2 - Hisar Naveen and V3 - Hisar Unnat and two planting system i.e. P1: Furrow Irrigated Raised Bed Planting and P2: Flat Bed Planting. The eighteen treatment combinations were tested in split plot design with three replications. Growth parameters like plant height, leaf area index and dry matter accumulation was measured after 20 days after sowing at 10 days intervals. Yield and yield attributes were measured by taking three plants randomly from each plot and biological parameters were recorded. Pod weight per plant was calculated by taking pods from four selected plants which were separated and weighed and then mean pod weight per plant was calculated.Similarly, number of pods per plant was measured by counting number of pods and mean number of pod per plant was calculated.

Statistical analysis:

The data used in the study are the mean values of replicated observations. Online computer programme **OPSTAT** was used for all the statistical analysis (http://hau.ernet.in/sheoranop/) of the research field data.

RESULTS AND DISCUSSION

Weather condition during crop growth period as per date of sowing:

The weekly weather parameters during the crop season (From 10th to 25th standard meteorological weeks) are given in Figure 1. The rainfall during crop season 2013 was deficient over Hisar region and it was observed that there were very few occasions when rainfall was above normal during the season. There were only five weeks throughout the season when rainfall was received with very low amount and rest of season was dry. The mean values of daily maximum and minimum temperature were 34.2 ^{O}C and 22.1 ^{O}C as against normal of 31.5 ^{O}C and 21.8 ^{O}C during 2013. The mean monthly maximum temperature deviations from normal were not much but the monthly minimum

temperature deviation in the month of May-June was 1.2 ^{O}C above/below the normal. The values of morning and evening relative humidity were 68.4 % and 35.9 % against normal values of 72.4 % and 38.4 % during *kharif* season. The weekly morning relative humidity was below normal throughout the season except in two weeks and weekly evening relative humidity were one weeks. The average daily mean sunshine hours recorded were 7.8 hours against the normal values of 7.7 hours. The maximum sunshine hours recorded were 10.4 hours during 16 SMW month whereas, the minimum 4.2 hours during 24th SMW.

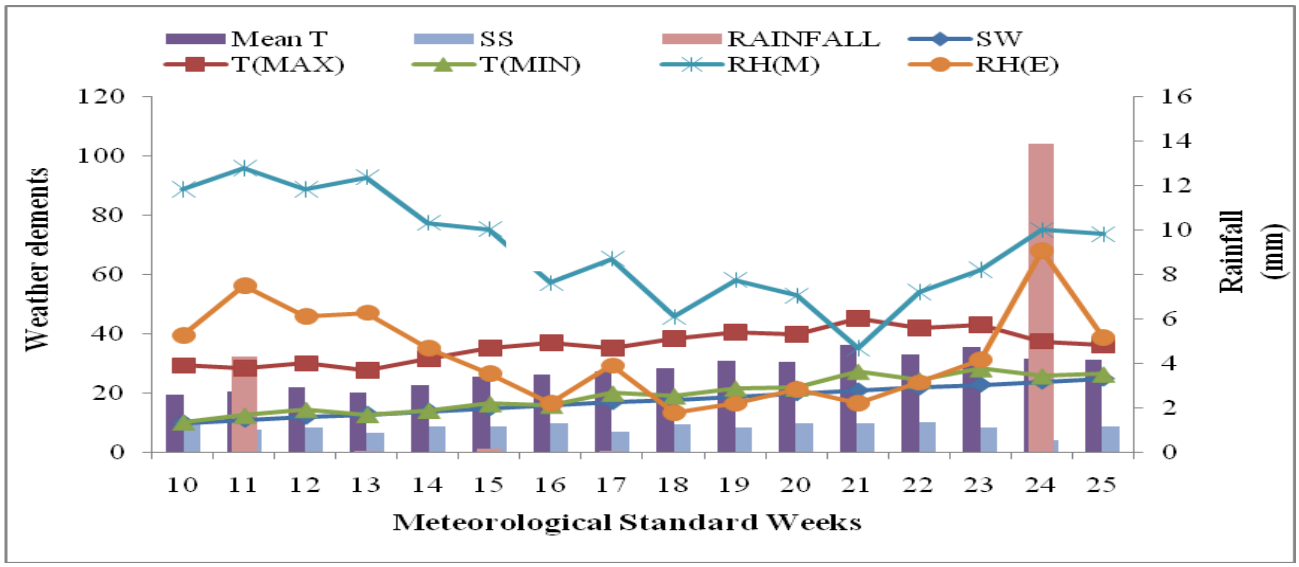

Fig. 1: Mean weekly meteorological data during crop season (2013)

Growth parameters

Plant height:

The plant height of okra varieties under different dates of sowing were recorded at various growth intervals (Table 1). The plant height significantly affected by delay in sowing. Plant height was higher in second sown crop (D_2) i.e., 112.15 cm as compared to first (D_1) and third (D_3) sown crop which were 110.46 and 109.83 cm, respectively. Among the okra varieties, Hisar Naveen produced the tallest crop with height of 113.54 cm at 90 DAS. The next variety with higher plant height was Hisar Unnat with 110.85 cm and the least height was of Varsha Uphar i.e., 108.41 cm. In case of planting pattern, furrow irrigated raised bed planted crop was tallest at all the growth stages.

Table 1: Effect of different treatments on plant height (cm) of okra crop at various growth stages

Treatments	Days after Sowing							
Dates of sowing	20	30	40	50	60	70	80	90
D_1- 1st week of March	11.41	16.95	27.43	41.05	65.87	81.09	98.13	110.46
D_2- 2nd week of March	12.14	17.88	28.80	42.67	67.26	83.91	98.96	112.15
D_3- 3rd week of March	10.47	15.98	26.23	39.81	64.46	78.13	96.53	109.83
CD (at 5 %)	1.12	0.95	1.03	1.20	1.32	0.68	1.18	0.95
Varieties								
V_1- Varsha Uphar	10.27	15.71	26.85	39.17	63.96	78.67	95.85	108.41
V_2- Hisar Naveen	12.06	18.86	28.76	42.87	67.45	82.03	99.16	113.54
V_3- Hisar Unat	11.87	16.71	27.09	41.99	65.74	80.86	98.90	110.85
CD (at 5 %)	1.13	1.10	1.99	2.09	3.69	0.65	2.51	2.01
Planting Systems								
P_1- Furrow irrigated raised bed planting	12.24	17.83	28.96	42.31	68.79	82.67	99.50	111.90
P_2- Flat bed planting	11.06	16.17	23.44	40.69	61.31	78.05	96.80	110.10
CD (at 5 %)	1.42	1.50	1.69	1.46	2.11	1.22	1.95	NS

Leaf Area Index:

Leaf Area Index (LAI) was maximum at 90 days after crop sowing in all the treatments (Table 2) because crop was in the active growing phase at this time. The LAI significantly affected by delay in sowing in all the varieties and the planting system at all growth stages. Leaf Area Index (LAI) was higher in second week of March sown crop (D_2) i.e., 2.88 as compared to first (D_1) and third (D_3) sown crop which were 2.78 and 2.60, respectively and it attained peak value at 80 days after sowing and thereafter decreased. Among the varieties of okra Hisar Naveen was found to lead in LAI (2.83) at all the growth intervals followed by Hisar Unnat (2.79) and least was found in case of Varsha Uphar (2.64). Among the planting systems, furrow irrigated raised bed planted crop with a value of 2.95 was found to lead in LAI at all the growth intervals than that of flat bed sown crop (2.56). It was observed that maximum LAI in all treatments was found at 80 days after sowing and thereafter showed decrease in LAI.

Table 2: Leaf area index (LAI) of okra varieties at various growth intervals under different growing environments

Treatments	Days after Sowing							
Dates of sowing	20	30	40	50	60	70	80	90
D_1 - 1st week of March	0.19	0.34	0.90	1.06	1.78	2.11	2.78	2.11
D_2- 2nd week of March	0.21	0.39	0.94	1.18	1.82	2.17	2.88	2.56
D_3- 3rd week of March	0.16	0.30	0.88	1.01	1.72	1.98	2.60	1.90
CD (at 5 %)	0.04	0.07	0.33	0.1	0.42	0.08	0.06	0.36
Varieties								
V_1- Varsha Uphar	0.17	0.31	0.79	1.05	1.73	1.93	2.64	1.94
V_2- Hisar Naveen	0.20	0.40	0.98	1.12	1.82	2.13	2.83	2.51
V_3- Hisar Unat	0.18	0.33	0.95	1.09	1.78	2.07	2.79	2.14
CD (at 5 %)	0.02	0.04	0.09	0.03	0.08	NS	0.05	0.02
Planting systems								
P_1- furrow irrigated raised bed planting	0.20	0.36	0.92	1.20	1.83	2.11	2.95	2.37
P_2- flat bed planting	0.17	0.33	0.89	0.97	1.72	2.04	2.56	2.03
CD (at 5 %)	0.01	0.15	0.03	0.08	0.07	0.02	0.01	0.05

Accumulation of dry matter (dry biomass):

Accumulation of dry biomass is a good index to express the photosynthetic efficiency of crop plants. Dry biomass increased with the advancement of crop stage and maximum was observed at 80 days after sowing (DAS) stage in all treatments (Table 3). Among sowing dates, D_2 (31.16 g/plant) accumulated more biomass as compare to D_1 (27.18 g/plant) and D_3 (24.21

Table 3: Dry matter (g/plant) of okra crop at various growth intervals under different growing environments

Treatments	Days after Sowing							
Dates of sowing	20	30	40	50	60	70	80	90
D_1- 1st week of March	1.69	1.88	4.99	7.56	15.22	20.19	27.18	25.48
D_2- 2nd week of March	1.78	2.39	5.98	8.67	17.38	24.29	31.16	28.52
D_3- 3rd week of March	1.24	1.56	4.43	5.63	12.17	16.59	24.21	23.67
CD (at 5 %)	0.56	0.33	0.21	0.27	0.13	1.25	1.62	0.46
Varieties								
V_1- Varsha Uphar	1.52	1.87	4.96	6.85	13.89	18.53	26.18	22.38
V_2- Hisar Naveen	1.61	2.01	5.38	7.96	15.88	21.85	28.53	25.50
V_3- Hisar Unat	1.58	1.95	5.06	7.15	15.01	20.76	27.98	24.30
CD (at 5 %)	0.17	0.01	0.04	0.16	0.55	0.38	0.70	0.56
Planting systems								
P_1- furrow irrigated raised bed planting	1.62	2.05	5.30	7.43	15.88	21.65	29.20	25.38
P_2- flat bed planting	1.59	1.85	4.96	6.96	14.08	19.15	26.69	22.79
CD (at 5 %)	0.06	0.03	1.02	1.00	1.15	1.33	1.01	0.34

g/plant) dates of sowing and it was maximum at 80 days after sowing among all the growth intervals. Among the varieties, Hisar Naveen produced maximum dry matter per plant (28.53 g/plant) followed by Hisar Unnat (27.98 g/plant) and Varsha Uphar (26.18 g/plant) at 80 days after sowing and thereafter showed a little decrease. Among the planting systems, furrow irrigated raised bed planted crop accumulated maximum dry matter (29.20 g/plant) than that of flat bed planting system (26.69 g/plant) at 80 days after sowing and thereafter showed a little decrease.

Yield and yield attributes:

Fruit diameter:

The highest fruit diameter (1.41 cm) was recorded in second date of crop sowing (14th March) and minimum (1.35 cm) was recorded in third date of crop sowing (22nd March). In case of varieties, the fruit diameter was highest in variety, Hisar Naveen (1.44 cm) followed by Hisar Unnat (1.40 cm) and Varsha Uphar (1.32 cm). The maximum value for fruit diameter (1.40 cm) was recorded in furrow irrigated raised bed planted crop and minimum fruit diameter (1.37 cm) was recorded in flat bed planted crop (Table 4).

Fruit length:

Data presented in (Table 4) revealed that the highest fruit length (8.70 cm) was recorded in second week of March sown crop (14th March) and minimum (8.02 cm) was recorded in third date of crop sowing (22nd March). In case of varieties, the fruit length was higher in Hisar Naveen (8.52 cm) followed by Hisar Unnat (8.33 cm) and Varsha Uphar (8.10 cm). The maximum fruit length (8.20 cm) was recorded in furrow irrigated raised bed planted crop and minimum fruit length (8.00 cm) was recorded in flat bed planted crop.

Table 4: Effect of different treatments on fruit parameters and fruit yield of okra crop

Treatments	Fruit diameter (cm)	Fruit length (cm)	No. of fruits plant^{-1}	Fruit yield (q ha^{-1})
Dates of sowing				
D_1- 1st week of March	1.39	8.41	30.44	84.22
D_2- 2nd week of March	1.41	8.70	33.18	88.71
D_3- 3rd week of March	1.35	8.02	27.30	81.80
CD (at 5 %)	NS	0.02	NS	0.17
Varieties				
V_1- Varsha Uphar	1.32	8.10	28.44	80.44
V_2- Hisar Naveen	1.44	8.52	32.20	87.23
V_3- Hisar Unat	1.40	8.33	30.26	86.34
CD (at 5 %)	0.036	NS	0.98	1.22
Planting systems				
P_1- furrow irrigated raised bed planting	1.40	8.20	31.50	86.20
P_2- flat bed planting	1.37	8.00	29.40	83.60
CD (at 5 %)	NS	0.01	1.10	2.3

Number of fruits plant^{-1}:

The highest number of fruits plant^{-1} (33.18) was observed in second date of crop sowing (14th March) and lowest (27.30) was recorded in third date of crop sowing, 22nd March (Table 4). Data further indicates that in case of varieties, the number of fruits plant^{-1} was higher in Hisar Naveen (32.20) as compared to Hisar Unnat and Varsha Uphar (30.26 and 28.44). Whereas, in furrow irrigated raised bed planted crop, the maximum number of fruits plant^{-1} (31.50) was obtained and minimum number of fruits plant^{-1} (29.40) was observed in flat bed planted crop.

Fruit yield:

Data (Table 4) revealed that best fruit yield was obtained when crop was sown in second week of March. Fruit yield was obtained maximum (88.71 q ha^{-1}) in second date of crop sowing (14th March) and lowest (81.80 q ha^{-1}) was recorded in third date of crop sowing (22nd

March). Among the various okra varieties, Hisar Naveen recorded the highest fruit yield (87.23 q ha^{-1}) followed by Hisar Unnat (86.34 q ha^{-1}) and lowest fruit yield (80.44 q ha^{-1}) was found in Varsha Uphar. In case of planting systems, the highest fruit yield (86.20 q ha^{-1}) was obtained in crop planted in furrow irrigated raised bed planting conditions and lowest (83.60 q ha^{-1}) was observed in flat bed planted crop.

Relationship of crop parameters with weather parameters

The correlation and regression analysis were carried out to quantify the relationship ofgrowth and yield of okra with weather parameters: maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and sunshine hours for crop with pooled data.The data (Table 5) on correlation between weather parameters and yield and yield attributes indicate that growth and yield of okra showed positive correlation with maximum and minimum temperature and negatively correlated with morning and evening relative humidity. Correlation between sunshine hours with yield and yield attributes was found to be non-significant (Table 5).

Table 5: Correlation of fruit parameters of okra crop withdifferent weather parameters

Weather parameters	Fruit yield			Fruit length			Fruit diameter			No. of fruits per plant		
	DOS	Varieties	Planting system	DOS	Varieties	Planting system	DOS	Varieties	Planting system	DOS	Varieties	Planting system
T_{max}	0.89**	0.84**	0.91**	0.87**	0.79**	0.86**	0.87**	0.91**	0.87**	0.82**	0.78**	0.79**
T_{min}	0.78**	0.65*	0.81**	0.75**	0.66*	0.73*	0.75**	0.63*	0.74*	0.69*	0.66*	0.68*
RH_{mor}	-0.90**	-0.83**	-0.89**	-0.92**	-0.83**	-0.89**	-0.88**	-0.90**	-0.91**	-0.77**	-0.78**	-0.79**
RH_{eve}	-0.77**	-0.71*	-0.79**	-0.88**	-0.77*	-0.81**	-0.81**	-0.84**	-0.87**	-0.68*	-0.63*	-0.66*
SSH	-0.52	-0.38	0.40	-0.39	-0.63	0.14	0.16	-0.76	0.25	0.72	-0.45	-0.27

$T_{max.}$ = Daily maximum temperature (^0C) $T_{min.}$ = Daily minimum temperature (^0C) RH_{mor}= Relative humidity morning RH_{eve}= Relative humidity evening SSH = Sunshine hours
**-Significance at 5% level **-Significance at 1% level*

Crop parameters:

Leaf area index (LAI) and dry matter (DM) accumulation was observed higher in 14th March sown crop as compared to 6th and 22nd March sown crop. Similarly leaf area index and dry matter accumulation were lowest when crop was sown on 22nd March under flat bed planting system. This might be due to more time available for crop growth and development in 14th March sown crop which resulted better leaf area. Increased leaf area contributes more accumulation of dry matter in plant. The reduction in LAI with delay in sowing was because of reduced vegetative phase and shorter days led to the quick occurrence of reproductive stage thereby life cycle of the crop became shorter. These findings are in tune with those of Kumari and Rao (2005) and Tripathi (2005). Among okra varieties, Hisar Naveen produced higher leaf area index and dry matter accumulation as compared to Hisar Unnat and Varsha Uphar under under furrow irrigated raised bed planting and flat bed planting systems. This was due to because of more absorption PAR in Hisar Naveen as compared to other varieties. The maximum value of yield attributes (number of fruits $plant^{-1}$, fruit diameter, fruit length and fruit yield) were observed in 14th March sown crop as compared to 6th and 22nd March sown crop. Similar findings were reported by Islam *et al.* (2000) who reported high pod and seed yield from July sowings compared to late August and October sowings. Higher seed yield of a number of okra cultivars were obtained from June sowings compared to late July sowings (Shujat *et al.*, 2006). Soomro *et al.* (2000) while studying on the optimum time of sowing concluded that crop sown from 5th to 20th March may gave highest yield as compared to early or late sown under Sakrand conditions.

Among the okra varieties, the yield was more in Hisar Naveen as compared to Hisar Unnat and Varsha Uphar under under furrow irrigated raised bed planting and flat bed planting systems. It might be due to more PAR absorption and due to higher LAI in Hisar Naveen as compared to Hisar Unnat and Varsha Uphar, which might have also caused reduction number of fruits $plant^{-1}$, fruit diameter and fruit

length. The yield of okra and its attributes were higher in crop sown on 14th March sown crop as compared to 6th and 22nd March sown crop in all the treatment combinations which might be because of the better microclimate (higher temperature and lower humidity) prevailing in early sown crop. This might have resulted in better crop growth in this season. Similarly Farooq *et al.* (2011) found that yield and yield attributes were significantly higher in early sown crop as compared to late sown conditions while Saroya *et al.* (1984) while determining the optimum sowing period of cotton under variable microclimatic conditions. Yadav and Varshney (2005) reported that the early sowing pearlmillet crop produced significantly higher grain yield as compare to delayed sowing. Kaushik and Kapoor (2007) observed that significant differences with environment were observed for days taken to 50 percent flowering, no of bolls/ plant, seed cotton yield. Patil *et al.* (2009) reported that seed cotton yield was significantly more in early sown crop.

Relationship of microclimate with growth and yield of Okra

Growth and yield of okra showed positive correlation with maximum and minimum temperature when crop was sown under three different sowing environment i.e., 14th March, 6th and 22nd March. However, the correlation with maximum and minimum temperature was highly significant. In case of relative humidity, growth and yield of okra showed negative correlation with morning and evening relative humidity when crop was sown on 14th March, 6th and 22nd March but the correlation was not significant with evening relative humidity. Under medium (14th March) and late sown conditions (22nd March) both morning and evening relative humidity was negatively correlated but correlation with relative humidity at evening was found to be not significant. Also wind speed was negatively and significantly correlated when crop was sown under three different sowing environments.

The pooled data of growth and yield of okra showed significantly positive relationship with sunshine hours, significantly negative with relative humidity and wind speed. Growth and yield of okra showed highly significant positive relationship with maximum and minimum temperature. Maximum and minimum temperatures exerted significant negative influence on yield of cotton (Prasad *et al.,* 2008). Growth and yield of cotton severity illustrated, on the whole, an imperative negative correlation with maximum and minimum temperatures and wind velocity (Rashida *et al.,* 2010).

For the crop sown on 6th March, variability in growth and yield of okra could be explained upto 80 % by vapour pressure deficit at morning and Hisar Naveen, 84% by vapour pressure deficit for Hisar Unnat and 86 % by vapour pressure deficit for Varsha Uphar. The accuracy of the above model can be improved with the addition of maximum temperature in case of Varsha Uphar and relative humidity in Hisar Naveen and Hisar Unnat. Variability in growth and yield of okra could be explained upto 77, 78 and 76 % by minimum temperature for Hisar Naveen, Hisar Unnat and Varsha Uphar sown on 14th March. The accuracy can be improved in above model by the addition of wind speed. The minimum temperature and wind speed in Hisar Naveen, Hisar Unnat and Varsha Uphar explained the variability upto 90, 75 and 85 % respectively when the data of both the growing environment was pooled. According to Singh (2010) linear regression analysis also revealed that meteorological parameters i.e., temperature and relative humidity along with vector of growth and yield of cotton played a significant role in appearance of the disease.

It can be concluded from results of the study that, distinctive growth, development and yield of okra were observed in all the three growing environment.The leaf area index, dry matter accumulation, yield and yield attributes were maximum when crop was sown on 2nd week of March. Among the planting systems, furrow irrigated raised bed planting system recorded maximum LAI, dry matter accumulation and yield and yield attributes. Hisar Naveen produced the highest LAI, dry matter accumulation and yield and yield attributes. Therefore, for okra cultivation, accurate choice of date of sowing and variety is highly important for producing higher yield. Further studies on these characteristics of okra in various other combintions would facilitate the establishment of high quality okra cultivation and production.

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