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Agrometeorological aspects of okra (*Abelmoschus esculebtus*) in arid subtropical regions of Haryana

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ABSTRACT

Climate variability is one of the most significant factors influencing year to year crop production, even in high-yield and high technology agricultural areas. An experiment was conducted to study the impact of microclimate on agrometerological (GDD, HTU, PTU, HUE and RUE) characteristics of okra. The main plot treatments consist of three dates 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 - VarshaUphar, V2 - Hisar Naveen and V3 - HisarUnnat 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.The agrometerological indices required for the maturity of okra crop was highest in okra sown in 3rd week of March and lowest in 1st week of March sown crop under both furrow irrigated raised bed and flatbed planting systems. The more GDD, HTU and PTU were required by HisarUnnat as compared to Hisar Naveen and VarshaUphar under furrow irrigated raised bed and flatbed planting systems during allthe three growing environments.

Key Words: Agrometerological indices, varieties, planting system, microclimate and Okra

INTRODUCTION

Okra, (*Abelmoschusesculentus*(L.) Moench) is an important vegetable crop consumed worldwide. It is a member of the *Malvaeceae* family. It is widely cultivated in the tropics and subtropics for its immature edible green fruits and consumed as a vegetable, raw, cooked or fried. It is a common ingredient of soups and sauces. The fruits can be conserved by drying or pickling. The leaves are sometimes used as a substitute for spinach. The tender fruits, leaves and succulent shoots are consumed, either in fresh or dried form.The fruit is a greenish capsule, slightly curved, six-chambered pods of fibrous texture, containing numerous seeds (Lengsfeld*etal*., 2004). The thick slimy juice of the fruit makes it a relish and a thickener of stews and contains vitamin C and some minerals such as phosphorus, calcium and potassium and has larger concentration ofthiamine, riboflavin and niacin than many vegetables (Ranganna, 1979).It is a source of carbohydrate, dietary fibre, fat and protein. It is a source of carbohydrate, dietary fibre, fat and protein (Asawalam*et al.,* 2007). Okra seeds serve as a good substitute for coffee and contain a considerable amount of good quality oil. Its consumption among other fruit vegetables was found beneficial in moderating blood pressure, fibrinogen concentration and plasma viscosity in Nigerian hypertensives" (Adebawoo*et al.,* 2007). Okra requires a long, warm and humid growing climate for better yield. It is sensitive to frost and extremely low temperatures. The okra plant requires warm temperatures and is unable to withstand low temperatures for long or tolerate any threat of frost. Optimum temperature is in the range of 21 to 30 ^{0}C, with minimum temperature of 18 ^{0}C and maximum temperature 35 ^{0}C (Abd-El-Kader *et al.*, 2010). Adjustment of climatic factors helps in taking more than one crop at north Indian plains and almost year-round cultivation under moderate climate in south India. The suitable environment for seed production is low precipitation, low relative humidity and high light intensity with hot and dry conditions during seed ripening (Dhankhar*et al.,* 2012). Agroclimatic indices i.e., growing degree days, photothermal and heliothermal units are useful for assessing the agroclimatic resources in crop planning and reflecting the impact of agro meteorological variables at different crop growth stages. 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

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virus disease area under this crop is decreasing during the rainy season. Moreover, when the crop is 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. 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 5^{th} to 20^{th} May which gives highest yield as compared to early or late sown under Sakrand conditions. Further, Elhag and Ahmed (2014) reported that the best vegetative growth and yield were obtained at 1^{st} July as compared to other dates of sowing. The effect of microclimate on vegetables has not been much studied in India. Consequently, it is difficult to guide the farmers regarding the agro meteorological aspects of this crop during summer season. Keeping this in view, the present study was planned with the objective to assess agrometeorological aspects of okra in arid subtropical regions of Haryana.

MATERIALS AND METHODS

Experimental site and location: The experiment was conducted during summer season 2013 at Research farm of Department of Vegetable Science, 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.The climate of Hisar region owes to its continental location on the outer margins of the monsoon region i.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: 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 - VarshaUphar, V2 - Hisar Naveen and V3 - HisarUnnat 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.

Methodology

(a) Growing degree days: Growing degree days (GDD) were determined by summing the daily mean temperature above base temperature and are expressed in ^{0}C day. This was calculated using the following formula:

Growing degree days (^{0}C day)

$$= \sum \left(\frac{T_{max.} + T_{min.}}{2} - T_b \right)$$

Where,

a = Date of start of a phenophase
b = Date of end of the phenophase
$T_{max.}$ =Daily maximum temperature (^{o}C)
$T_{min.}$ =Daily minimum temperature (^{o}C)
T_b = Base temperature (10 ^{o}C, Senshan*et al.*, 1995)

(b) Heliothermal unit: Heliothermal units (HTU) for a day represent the product of heat growing degree days (GDD) and bright sunshine hours for that day and are expressed in ^{o}C day hours. The sums of HTU for particular phenophases of interest were determined according to the equation:

HTU (^{0}C day hours) = ∑ (GDD x BSS)

Where, BSS = Bright sunshine hours

(c)Photothermal unit: Day and night is one of the basic factors controlling the period of vegetative growth in a photosensitive crop. Photothermal units (PTU) are cumulative value of growing degree days multiplied by maximum possible sunshine hours and are expressed in ^{0}C day hours. PTU was calculated using the following formula:

PTU (^{0}C day hours) = Σ (GDD x N)

Where, N = Maximum possible sunshine hours or day length

(d)Radiation Use Efficiency: The radiation use efficiency is a ratio of biological yield and the radiation intercepted. It can be expressed by the following formula:

Radiation use efficiency (RUE) = Dry matter / Intercepted PAR

Where, PAR= Photosynthetically Active Radiation

(e)Heat use efficiency: Heat use efficiency (HUE) was calculated as the ratio of dry matter (DM) and growing degree days (ΣGDD) between any two consecutive phenological stages of the crop. It can be expressed by the following formula:

$$HUE\ (g/m^2/{}^0C\ day) = \frac{DM\ (g/m^2)}{\Sigma\ GDD\ ({}^0C\ day)}$$

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 68.43 % and 35.85 % 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 months whereas, the minimum 4.2 hours during 24th SMW.

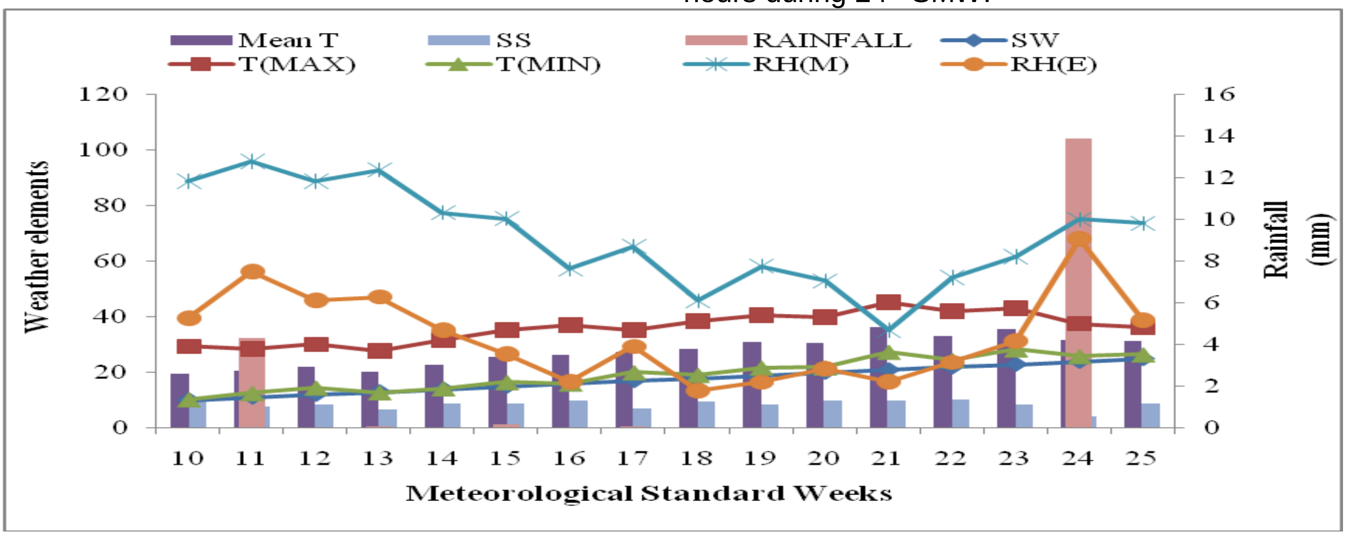

Fig. 1: Mean weekly meteorological data during crop season (2013)

Agrometerological studies

Growing degree days:

Growing degree days or thermal time requirement for completion of different phenological stages of okra under different treatments were worked out during the crop season and are presented in Table 1. The cumulative thermal time requirements were significantly higher in third date of sowing (22nd March) as compared to first and second date of crop sowing at all the phenological stages. These values at first harvesting stage were 565.46, 586.74 and 706.82^{0}C day in D_1, D_2 and D_3 during season 2013, respectively. Among the varieties, highest number of growing degree days were accumulated (705.05) by Hisar Unnat followed by Hisar Naveen (621.79 and the least growing degree days were accumulated by Varsha Uphar (532.46 ^{0}C day). The planting system also influenced the thermal time requirement of okra crop. Which was significantly higher in flat bed system (632.74) as compared to raised bed planting system (614.02 ^{0}C day).

Table 1: Effect of different treatments on growing degree days (^{0} C day) at various phenophases of okra crop

Treatments			
Dates of sowing	Germination	50% Flowering	First harvesting
D_1 -1st week of March	60.02	499.70	565.46
D_2 -2nd week of March	60.54	532.91	586.74
D_3 -3rd week of March	74.72	611.47	706.82
Varieties			
V_1 -VarshaUphar	59.22	468.90	532.46
V_2 -Hisar Naveen	62.60	542.92	621.79
V_3 -HisarUnnat	72.64	623.72	705.05
Planting systems			
P_1 -Raised bed	63.56	530.80	614.02
P_2 -Flat bed	74.15	560.55	632.74

Heliothermal units (HTU):

The cumulative value of HTU for first harvesting was higher in third date sown crop (D_3) as compared to first (D_1) and second (D_2) sown crops in all the treatments (Table 3). The late sown okra crop showed higher consumption of HTU as compared to early sown crop. This might be due to delayed maturity in late sown as compared to early sown crop. The cumulative value of HTU at first harvesting stage of D_1, D_2 and D_3 were 3893.23, 4273.47 and 5394.15 ^{0}C day hour, respectively. Among okra varieties HisarUnnataccumulated highest amount of HTU with the value of 5095.26 ^{0}C day hour.

Table 2: Effect of different treatments on heliothermal units (^{0}C day hour) at various phenophases of okra crop

Treatments			
Dates of sowing	Germination	50% Flowering	First harvesting
D_1 -1st week of March	399.16	3366.09	3893.23
D_2 -2nd week of March	410.01	3483.69	4273.47
D_3 -3rd week of March	545.00	4421.63	5394.15
Varieties			
V_1 -VarshaUphar	383.87	3376.80	3621.28
V_2 -Hisar Naveen	518.90	4413.87	4845.31
V_3 -HisarUnnat	452.26	3482.40	5095.26
Planting systems			
P_1 -Raised bed	429.72	3440.81	4257.92
P_2 -Flat bed	473.28	4074.45	4783.08

The next variety with higher accumulation was Hisar Naveen, i.e., 4845. 31 ^{0}C day hour and the least HTU were accumulated by the VarshaUphar i.e., 3621.28 ^{0}C day hour. In case of planting pattern, flat bed sown crop accumulated highest amount of HTU with the value of 4783.08 ^{0}C day hour as compared to raised bed sown crop (4257.92 ^{0}C day hour).

Photothermal units (PTU)

The phenophases wise variation in phototermal units among different dates of sowing during crop season are presented in Table 3. The cumulative value of PTU at first harvesting was higher in third date sown crop (D_3) as compared to second (D_2) and first (D_1) sown crop in all the treatments. The late sown okra crop showed higher consumption of PTU as compared to early sown okra crop. This might be due to delayed maturity in late sown as compared to early sown okra crop. Similar trend as that of heat units was also observed in PTU values in planting systems. The cumulative values of PTU at harvesting stage of D_1, D_2 and D_3 were 7718.16, 8030.09 and 9694.81 ^{0}C day hours, respectively. Among okra varieties HisarUnnataccumulated highest amount of PTU with the value of 9168.45 ^{0}C day hours followed by Hisar Naveen(8737.41 ^{0}C day hours) and the least PTU were accumulated by VarshaUphar(7538.20 ^{0}C day hours). Flat bed sown crop accumulated highest amount of PTU with the value of 8625.80 as compared to raised bed (8336.68 ^{0}C day hour).

Table 3: Effect of different treatments on phototermal units (^{0}C day hours) at various phenophases of okra crop

Treatments			
Dates of sowing	Germination	50% Flowering	First harvesting
D_1 -1st week of March	854.59	6363.62	7718.16
D_2 -2nd week of March	664.94	6139.07	8030.09
D_3 -3rd week of March	1078.08	6808.04	9694.81
Varieties			
V_1 -VarshaUphar	634.50	5938.44	7538.20
V_2 -Hisar Naveen	1018.71	6967.75	8737.41
V_3 -HisarUnnat	944.48	6403.81	9168.45
Planting systems			
P_1 -Raised bed	987.63	6675.02	8336.68
P_2 -Flat bed	743.72	6197.98	8625.80

Radiation use efficiency (RUE)

The okracrop sown in firstweek of March was most efficient in PAR utilization as compared to crop sown in second and third week of March (Table 4). Though the amount of PAR received above the canopy was almost same in all treatments, the amount of intercepted PAR differed because of differential crop cover owing to variation in LAI and varying levels of

Table 4: Effect of different treatments on radiation use efficiency (g/MJ) 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	0.058	0.098	0.15	0.24	0.34	0.58	0.68	0.76
D_2- 2nd week of March	0.095	0.11	0.19	0.26	0.37	0.62	0.69	0.78
D_3- 3rd week of March	0.062	0.10	0.16	0.22	0.31	0.56	0.65	0.72
Varieties								
V_1-Varsha Uphar	0.068	0.11	0.14	0.21	0.29	0.43	0.65	0.73
V_2- Hisar Naveen	0.071	0.13	0.18	0.26	0.36	0.47	0.69	0.78
V_3- HisarUnat	0.070	0.11	0.17	0.25	0.33	0.51	0.71	0.75
Planting systems								
P_1- furrow irrigated raised bed planting	0.12	0.13	0.20	0.28	0.36	0.62	0.70	0.79
P_2- flat bed planting	0.09	0.10	0.16	0.20	0.33	0.53	0.63	0.70

biomass production in different treatments, implying that RUE also differed. Hisar Naveen showed higher RUE followed by HisarUnnat and VarshaUphar at all growth stages. Radiation use efficiency was higher in second sown crop (D_2) i.e., 0.78 g/MJ as compared to first (D_1) and third (D_3) sown crop which were 0.76 and 0.72 g/MJ, respectively.Among okra varieties Hisar Naveenshowed highest radiation use efficiency with the value of 0.78 g/MJ at 90 days after sowing followed by HisarUnnat i.e., 0.75 g/MJ, and the least radiation use efficiency was of VarshaUphar i.e., 0.73 g/MJ. The furrow irrigated raised bed showed highest radiation use efficiency with the value of 0.79 g/MJ as compared to flat bed planting system (0.70 g/MJ).

Heat use efficiency (HUE)

Heat use efficiency showed an increasing trend with advancement of growth and attained maxima at the time of first harvesting. Heat use efficiency was higher in second sown crop (D_2) i.e., 0.432 $g/m^2/^0$ C day as compared to first (D_1) and third (D_3) sown crop which were 0.360 and 0.309 $g/m^2/^0$ C day, respectively (Table 5). The okra crop sown on second week of March was more efficient in heat unit's consumption over late sown crop. This might be due to maximum heat unit's consumption and dry matter production in second sown crop. Among the planting systems, furrow irrigated raised bed planting system was more efficient in heat unit consumption than that of flat bed planting system. This was because of higher heat unit consumption and dry matter production by former planting system as compared to latter planting system. Among okra varieties Hisar Naveenshowed highest heat use efficiency with the value of 0.403 $g/m^2/^0$ C day. The next variety with highest heat use efficiency was HisarUnnat i.e., 0.353 $g/m^2/^0$ C day, and the least heat use efficiency was of VarshaUphar i.e., 0.344 $g/m^2/^0$ C day. In case of planting system, furrow irrigated raised bed planting system showed highest heat use efficiency with the value of 0.369 $g/m^2/^0$ C day as compared to flat bedplanting system (0.365 $g/m^2/^0$ C day).

Table 5: Effect of different treatments on heat use efficiency ($g/m^2/^0$ C day) of okra crop at various growth stages

Treatments	Heat Use Efficiency	
Dates of sowing	50% Flowering	First harvesting
D_1- 1st week of March	0.347	0.360
D_2- 2nd week of March	0.392	0.432
D_3- 3rd week of March	0.306	0.309
Varieties		
V_1- VarshaUphar	0.313	0.344
V_2- Hisar Naveen	0.381	0.403
V_3- HisarUnat	0.346	0.353
Planting systems		
P_1- furrow irrigated raised bed planting	0.349	0.369
P_2- flat bed planting	0.346	0.365

Phenology:

The first sown crop (D_1) took more number of days to germinate (7 days), and flowering came in 41 days as compared to D_2 and D_3. However, for the germination phase, no much significant difference was observed among dates of sowing (Table 6). The third date sown crop (D_3) took more number of days for harvesting (46) as compared to D_2 (43) and D_1 (45). Among the okra varieties, Hisar Unnat (46) took more days to complete its life cycle, followed by Hisar Navven (45) and Varsha Uphar (44). Among the planting systems, furrow irrigated raised bed planted crop was found to have less number of days requirement to germinate (6), flowering (38) and maturity (45) than that of flat bed planted crop which required 7, 40 and 47 days for germination, flowering and first harvesting, respectively.

Table 6: Number of days taken for different phenophases by okra crop under different growing environments

Treatments			
Dates of sowing	Germination	50 % Flowering	First harvesting
D_1- 1st week of March	7	41	45
D_2- 2nd week of March	6	39	43
D_3- 3rd week of March	5	41	46
Varieties			
V_1- VarshaUphar	5	40	44
V_2- Hisar Naveen	5	38	45
V_3- HisarUnat	5	41	46
Planting systems			
P_1- furrow irrigated raised bed planting	6	38	45
P_2- flat bed planting	7	40	47

Agrometeorological indices

Thermal and radiation indices accumulated (GDD, HTU, PTU, HUE and RUE) at different phenophases were higher in 22 March sown crop as compared to 6 and 14 March sown crops under both furrow irrigated raised bed planting and flat bed planting conditions. This might be due to more days taken by 22 March sown crop to attain the different developmental phenophases and higher temperature experienced during latter season. Singh *et al.* (2007) found that heat unit requirements of different genotypes of cotton increased with advancement of crop growth i.e., from germination to maturity. Kaur and Hundal (2006) also reported that the heat units accumulated higher in early sown *Brassica sp*. as compared to middle and late sown crop. The values of thermal indices accumulated were also higher under furrow irrigated raised bed planting in all the treatment combination than that of flat bed planting conditions. This might be due to more penetration to lower canopy radiation in furrow irrigated raised bed planting than flat bed planting which caused faster development and matured earlier. In case of okra varieties, Hisar Unnatconsumed maximum heat unit as compared to Hisar Naveen and VarshaUphar. This might be due the fact that to more time was taken for maturity. Dhaliwal *et al.* (2005) observed that accumulated degree days during crop season of mustard were 287, 329 and 839 ºC days for first aphid population, maximum aphid population and the last aphid population respectively. Singh (2010) found that heat unit requirements of different genotypes of cotton increased with advancement of crop growth i.e., from germination to maturity. Gonias*et al.* (2012) reported that crop growth and yield varies among locations due to differences in environmental parameters, such as temperature, relative humidity, solar radiation and vapor pressure deficit.

Okra crop productivity (such as biological and economical yield) and phenophases of the crop were affected due to the climatic factor, agronomical and management. The agrometerological indices (GDD, HTU, PTU, HUE and RUE) required for the maturity of the crop was highest in okra sown on 22nd March and lowest in 6th March sown crop under both furrow irrigated raised bed and flat bed planting systems. The more GDD, HTU and PTU were required by Hisar Unnat as compared to Hisar Naveen and Varsha Upharunder furrow irrigated raised bed and flat bed planting systems. Therefore, it may be concluded that under improved management, there is a large potential for increasing the production under aberrant weather conditions for which crop weather interaction studies can be used advantageously as an aid to crop management.

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