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Impact of Microclimatic Factors on the Growth Stages of Sesame (*Sesamum indicum* L) Agro-Ecosystem for Betterment of Arid Zone Farming in the North-Western Arid Region of Rajasthan

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Abstract

The present study was done to understand the influence of microclimatic factors on the growth stages of sesame in the rain fed regions, of north-western arid region of district Bikaner (Rajasthan) India. The present study includes the following parameters: 1. Air temperature in °C, relative humidity in percentage and vapour pressure in mm of mercury at the ground surface and at different heights (5 cm, 15 cm, 30 cm, 60 cm and 100 cm). 2. Soil temperature in °C at ground surface and at different depths (5 cm, 15 cm and 30 cm). 3. Net radiations in g.cal/cm^2/minute. These agro-climatic parameters have been recorded on various stages *viz*. vegetative growth stages, flowering stage, (i.e., at 50% flowering) and capsule stage (i.e., at 50% capsule formation) by visual rating at different times of that day (i.e., 8.00, 14.00 and 18.00 hours in the kharif season of year 2014, 2015 and 2016 The research site was located in crop field of sesame at village Ridmalsar lying 20 km in North-East to the city Bikaner, Rajasthan, India and the investigation was carried out in randomized block design with six replications. Each replication was separated with a path of 1.0 m. and each sub-plot was separated by 50 cm path. The sesame variety studied was RT46 as this variety was introduced in last few years and was famous between local farmers for it drought resistant property, early maturity and high disease resistant quality. To study the influence of these parameters the climatic history of last ten year and also the water budget was analyzed. The meteorological data's were collected from KVK and the regional center of CAZRI (Central Arid Zone Research Institute Beechwal), Bikaner (Rajasthan). It can be concluded from present study that air temperature in profile, relative humidity distribution and also vapour pressure in the microclimatic zone (sesame agro-ecosystem) of the atmosphere varies with changes in the time of day (morning, noon and afternoon), change in height of profile (5, 15, 30, 60 and 100 cm) and stages of crop. The net radiation values also show increase from morning to noon in all the different stages of growth.

Keywords: Agroecosystem; Agroclimate (microclimate); Air temperature; Net radiation; Relative humidity; Soil temperature; Vapour pressure

Introduction

Climate is a major component of the environmental complex. In general, climate as, understood by the early Greek scientists includes the general condition of the atmosphere such as temperature, rainfall, humidity, wind and other variables these climatic factors are very crucial to understand the cropping pattern mainly in arid zone farming. Indian agriculture mostly depends on climate; major climatic factors which influence Indian agriculture on a great extent are Temperature, Solar radiation, Rainfall, Evapration, Relative humidity, wind velocity, Air temperature, Soil temperature etc. About 60% of total net sown area comes under rain fed lands. Rain fed crops account for 48% area under food crops and 68% under non-food crop the climate governs the cropping pattern and the production of crop [1]. Not only this, it determines to a great extent, human life and economy of a region. In relationship between crop and climate, the crop is dependent variable. Crop systems are complex and they depend in very complex ways on equally complex independent variables of weather and climate [2]. Slatyer [3] suggested that plant Climatologist must attempt to understand the pattern of energy and water cycling in plant communities in relation to growth development and yield.

Western Rajasthan constitutes 62% of the 0.32 million km^2 of total Thar Desert that make up the hot Indian arid region of which total cropped area cultivated of Bikaner region is 51.43% and 509907 in hectare (*Agricultural Stastics at a glance 2015-16 Department of Agriculture, Govt of Rajasthan). The average annual rainfall of the area varies from less than 100 mm (Coefficient of Variation [CV]=70% the Coefficient of Variation (CV) is a statistical measure of variability in the ratio of plant water demand to precipitation) in the western parts. The spatial variability of the long-term productivity (2005-2015) of sesame in western Rajasthan has been found to closely follow the variability of annual rainfall distribution. The Changing Climatic scenarios affect the productivity of rain fed sesame in the western parts of the region which constitute the region of Jodhpur division and Bikaner division and productivity of sesame varies from 382 kg/ha^{-1} to 205 kg/ha^{-1} average of last five year (Agricultural Stastics at a glance 2015-16 Department of Agriculture, Govt of Rajasthan). The probability of drought that affects sesame production also followed the variability of spatial distribution of rainfall. Such probability was highest (36%-40%) in the western part and lowest (21%-30%) in the northern and eastern parts of arid Rajasthan.

Lundegardh [4] has shown that the study of climate and its analysis is still in its infancy. This is particularly true in the analysis of the climate as related to plant growth and development in different areas of the growth and development in different areas of the earth. It was earlier recognized by Geiger [5] that climatic conditions differ near the ground and little above ground as well as underneath the ground that is the soil where plants and animal populations grow and multiply. It is precisely the air and soil layer near the ground surface which assumes special importance in an agro-ecosystem.

Geiger [5] designated this "ground air layer", a "plant climate" or a microclimate. The climate and other conditions where the plants actually grow are different from the macroclimate of any area. The macro-climatic and microclimatic parameters have been shown to be significant in the interpretation of organic productivity in an agro-ecosystem [6].

Materials and Methods

Drought tolerance oil seed crop sesame (*Sesamum indicum* L.) has been preferred for the present investigation and the variety studied was RT-46. RT-46 was selected for the study because this was the only variety which was adopted by a sizeable number of farmers. It was revealed that majority of the sesame growers found RT-46 variety suitable as they had adopted it in the seventh or eighth year of its release due to its early maturity i.e.,75-85 days and high resistance towards insect pests. Most of the sesame growers reported that the variety RT-46 was highly disease resistant as compared to the other varieties. The farmers could easily procure the seeds from local dealers and in required quantity.

The sesame crop has been under cultivation throughout arid and semi-arid zones of Rajasthan. Sesame is one of the most versatile crops that can be grown in dry arid regions. It has unique attributes that can fit most cropping systems and it is able to give profitable yield under non irrigated area. Sesame is very heat, drought, disease, and insect tolerant. Crops following sesame have increased yields with reduced production costs because of increased moisture retention and better soil tilth. In spite of these characters of RT-46 the final yield of crop was still not satisfactory, so the present study is designed to study the agro-climatic parameters which according to local farmers may be the possible reason of unsatisfactory yield.

These agro-climatic parameters have been recorded on various stages *viz.* vegetative growth stages, flowering stage, (i.e., at 50% flowering) and capsule stage (i.e., at 50% capsule formation) by visual rating at different times of that day (i.e., 8.00, 14.00 and 18.00 hours) in the year 2014, 2015 and 2016 at research site which was located in crop field of sesame at village Ridmalsar lying 20 km in North-East to the city Bikaner, Rajasthan, The layout of experiment was in randomized block design with six replications. Each replication was separated with a path of 1.0 m. and each sub-plot was separated by 50 cm path. In 2014, 2015 and 2016 the date of sowing was 17th july, 18th july and 25th july, the field were ploughed twice, soon after the first shower of rain in order to conserve the maximum amount of moisture in the soil with these two ploughing the fields were ready for sowing of the crop. The row to row spacing was 25 to 35 cm and plant to plant spacing was 10 cm to 20 cm. The study area was mono cropping, so the sesame crop allowed to with stand in the experimental trial up to 90 DS. In general, crop is harvested at 80 DS to 85 DS (days after sowing).

As the experimental site is located in arid region that is in western Rajasthan which have extreme climate and after analyzing the climatic data's of last ten years and also studying the normal climatic budget of Bikaner district from 2010 to 2015 it could be assumed that macroclimatic factor for two to three years does not dramatically changes so the agro climatic factors needed to study these parameters were taken as mean monthly and weekly data's of three cropping year that is kharif of 2014, 2015 and 2016 which are temperatures, relative humidity, wind velocity, precipitation, potential evapotranspiration and bright sun shine data obtained from the central arid zone Research Institute Farm, Beechwal (District Bikaner), and from Krishi Vigyan Kendra (KVK) Bikaner.

The study was mainly focused on growth stages only, as after analyzing the cropping history of sesame it was noticed that after successful sowing and planting of sesame when plant enters into these growth stages slight changes in climatic factor mainly air temperature, relative humidity, vapour pressure and soil temperature presumably affects the cropping pattern and ultimately the yield of sesame crop although data was collected and maintained on monthly and weekly basis of last three years and then average data was used to make a broad picture of impact of these microclimatic factors on sesame crop. The recorded observations have been presented in tables as mean of three years and recorded observations have been presented in Tables 1-5 and graphical presentation in Figure 1.

The parameters which were mainly focused are:

1. Air temperature in °C relative humidity in percentage and vapour pressure in mm of mercury at the ground surface and at different heights (5 cm, 15 cm, 30 cm, 60 cm and 100 cm).

2. Soil temperature in °C at ground surface and at different depths. The soil temperature at soil surface and depths of 5 cm, 15 cm, and 30 cm were recorded daily with the help of soil thermometer and averaged weekly from 26th to 40th standard week during the kharif of 2014, 2015 and 2016

3. Net radiation in g.cal/cm^2/minute.

The measurement of net radiation in a natural environment is difficult because of fact that net radiation includes evapotranspiration and energy that is used for heating soil is dissipated in the atmosphere. Lowry and Chilkote [7] devised a close approximation for net radiation estimation in the vicinity of plant communities with the help of Net Radiometer. Billings [8] quoted that the reflection and absorption pattern of solar radiation can be estimated by the temperature differences that develop between polished and black surface by the formula Rn=k(T)

Where k=equation constant equal to 0.163 and

T=difference between the temperature of the reflected (polished) and absorbed (black) surface at a particular time.

Results and Discussion

There was a general increase in the air temperature from morning to noon and decreasing trend from noon to evening. The downward trend was observed in percentage relative humidity from morning to evening. The vapour pressure distribution also showed a similar trend as relative humidity values. The highest air temperature (37.2°C) was observed in noon time. It increases with the increasing profile height (5 to 100 cm). The lowest temperature (24.0°C) was in the morning at 5 cm profile (Table 1). The relative humidity values were highest (80%) in the morning of vegetative growth stage and followed by capsule and flowering stages respectively. It might be due to high area index during the vegetative growth stage. The vapour pressure values were the highest (30.2 mm) in morning and the lowest (10.0 mm) in noon (Table 2).

Month	PE	P	AE	WD	MS	WRO	Ia (%)	Im (%)
January	53.0	5.2	5.0	48.0	0.0	0.0	90.56	-90.56
February	75.0	6.9	7.0	68.0	0.0	0.0	90.66	-90.66
March	131.0	6.4	6.0	125.0	0.0	0.0	95.4	-95.4
April	172.0	4.6	5.0	167.0	0.0	0.0	97.09	-97.09
May	237.0	12.5	13.0	224.0	0.0	0.0	94.51	-94.51
June	258	28.1	28.0	230.0	0.0	0.0	89.14	-89.14
July	228	85.5	86.0	142.0	0.0	0.0	62.28	-62.28
August	197.0	85.3	85.0	112.0	0.0	0.0	56.85	-56.85
September	178.0	44.2	44.0	134.0	0.0	0.0	75.28	-75.28
October	125.0	6.1	6.0	119.0	0.0	0.0	95.20	-95.20
November	68.0	1.9	2.0	66.0	0.0	0.0	97.0	-97.0
Decmber	49.0	4.0	4.0	45.0	0.0	0.0	91.83	-91.83

Table 1: Normal climatic water budget of Bikaner from 2010-2015 on month basis. Abbreviations used in water budget, PE=Potential evapo-transpiration (mm), P=Precipitation (mm), AE=Actual evaporation, WD=Water deficit (mm), MS=Moisture surplus (mm), WRO=Water runoff, Ia(%)=Aridity index percent, Im (%)=Moisture index percent.

S.NO	Profile Height (cm)	Vegetative Growth			Flowering Stage			Capsule Stage		
Day time		M	N	E	M	N	E	M	N	E
	05	25.0	31.2	29.5	24.2	34.2	32.4	24.0	33.8	32.0
	15	25.5	32.2	30.2	24.3	35.0	32.8	24.2	33.8	32.0
	30	26.0	32.7	30.8	24.4	35.3	33.3	24.2	34.7	33.8
	60	26.1	35.5	32.0	26.0	36.5	34.8	24.6	37.2	36.0
	100	26.2	35.2	32.0	25.3	36.0	34.8	24.6	37.2	36.0

Table 2: Agro climate of Sesame agro-ecosystem-Airtemperature distribution (°C). M=Morning or 8 hours, N=Noon or 14 hours, E=Evening or 18 hours.

The present study envies that air temperature in profile, relative humidity distribution and also vapour pressure in the microclimatic zone (sesame agro-ecosystem) of the atmosphere varies with changes in the time of day (morning, noon and afternoon), change in height of profile (5, 15, 30, 60 and 100 cm) and stages of crop (Tables 1-3). The highest air temperature (37°C) at about mid-day was at the boundary between the ground and air, and from this boundary the temperature decreases upward and downward. Similar results have been reported by Wilsie [6] and Ramdas that conductive, convective and radiative processes account for the large variations of temperature and humidity with time of day as well as with height above ground. The relative humidity at ground level follows that of the agro-climate (Table 4). In contrast to macroclimatic air temperature and temperature inside the crop, temperature increases with height forming an inversion.

S.NO	Profile Height (Cm)	Vegetative Growth Stage			Flowering Stage			Capsule Stage		
Day time		M	N	E	M	N	E	M	N	E
1.	05	80.0	44.0	27.0	61.0	33.0	25.0	69.0	29.0	19.0
2.	15	80.0	44.0	27.0	61.0	30.0	23.0	69.0	29.0	19.0
3.	30	68.5	34.0	26.0	61.0	30.0	23.0	68.5	28.5	19.0
4.	60	48.5	34.0	26.0	55.5	28.5	23.0	65.0	28.5	19.0
5.	100	45.0	30.5	26.0	50.0	28.5	23.0	65.0	28.5	19.0

Table 3: Agro climate of Sesame agro-ecosystem-Relative humidity distribution (°C).

S.No	Profile	Vegetative Growth	Flowering Stage	Capsule Stage

	Height (Cm)	Stage								
Day time		M	N	E	M	N	E	M	N	E
1.	05	30.2	21.8	15.0	19.0	15.5	14.0	13.2	11.0	11.8
2.	15	28.5	21.0	13.1	18.5	15.2	13.5	12.8	10.4	11.5
3.	30	23.2	18.0	13.0	18.0	14.8	13.8	12.5	10.2	11.3
4.	60	19.7	16.8	12.5	15.5	14.5	13.0	12.5	10.0	11.3
5.	10	17.5	16.5	12.0	14.4	12.5	13.0	12.0	10.0	11.0

Table 4: Agroclimate of Sesame agro-ecosystem-Vapour pressure distribution (mm Hg) M=Morning or 8 hours, N=Noon or 14 hours, E=Evening or 18 hours.

In vegetative growth stage the crop had slowly grown vertically and covers the ground more uniformly and appreciably affected the agro-climate. The agro-climate (microclimate) appears to be more stable than macroclimate due to the less variation in climatic parameters. The relative humidity at ground level follows that of the agro-climate (Figure 1). In contrast to macroclimatic air temperature and temperature inside the crop, temperature increases with height forming an inversion.

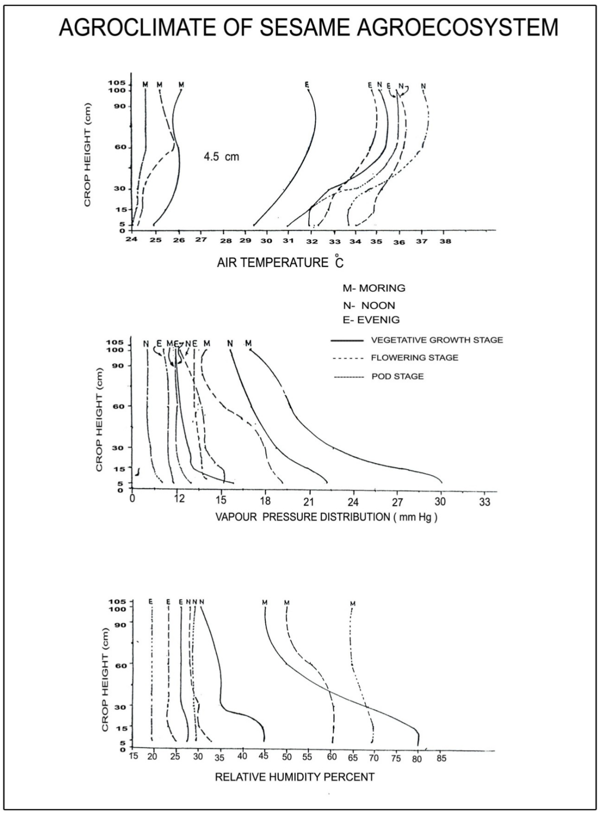

Figure 1: Agroclimate of Sesame agroecosystem.

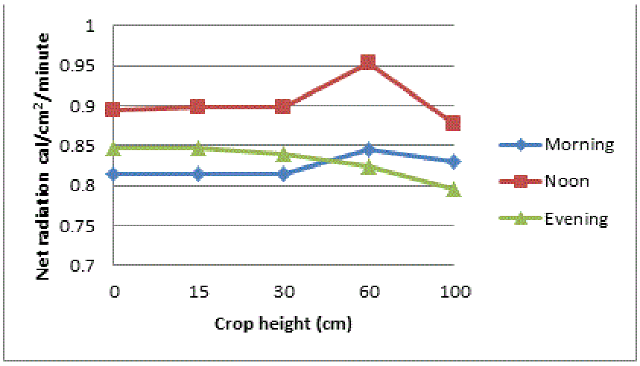

Figure 2: Net radiation (cal/cm^2/minute) at vegetative stage in Seame agro-ecosystem. (Mean values of last three kharif season 2014, 2015, 2016).

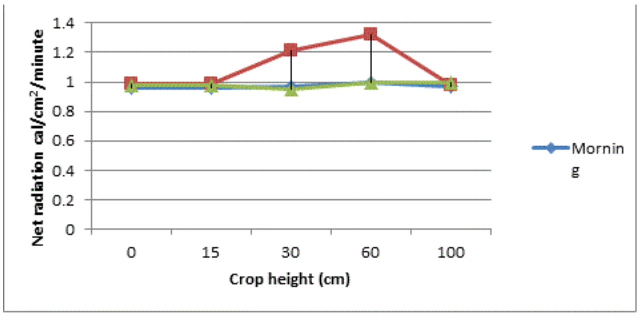

Figure 3: Net radiation (cal/cm^2/minute) at capsule stage in Seame agro-ecosystem.

The highest temperature (37°C) at about mid-day was at the boundary between the ground and air, and from this boundary the temperature decreases upward and downward. The net radiation values show increasing trend from morning to noon in all the different stages of growth. There had been slight increase at 60 cm height and then decrease (Table 5). At lower heights i.e., 5 cm, 15 cm and 30 cm, the net radiation remains almost same.

S. No.	Profile	Vegetative			Flowering			Capsule		
	Height (Cm)	Growth Stage			Stage			Stage		
		M	N	E	M	N	E	M	N	E
1.	05	0.8152	0.8937	0.8476	0.9280	0.9875	0.9430	0.9635	0.9825	0.9770
2.	15	0.1852	0.8990	0.8475	0.9300	0.9875	0.9430	0.9635	0.9825	0.9770
3.	30	0.8152	0.8990	0.8400	0.9300	1.0736	0.9455	0.9700	1.2116	0.9550
4.	60	0.8445	0.9530	0.8250	0.9780	1.220	0.9330	0.9925	1.3250	0.9980
5	100	0.8300	0.8765	0.7950	0.9200	0.9450	0.9300	0.9650	0.9780	0.9880

Table 5: Net radiation (cal/cm^2/minute) in Sesame agro-ecosystem. (Mean values of last three kharif season 2014, 2015, 2016), M=Morning, N=Noon, E=Evening.

The net radiation values shows increase from morning to noon in all the different stages of growth. There had been slight increase at 60 cm height and then decrease. At lower heights i.e., 5 cm, 15 cm and 30 cm, the net radiation remains almost same. It seems that at lower profiles the intervening difference in heights, for taking observations i.e., in between 5 cm and 15 cm to 30 cm have not been sufficient for net radiation measurement (Table 4, Figures 2 and 3).

Agro-climatic studies conclude that microclimatic parameters under study (Table 6) varied with the time of day, height profile and stages of crop (Figure 3).

S.No	Standard	Morning				Noon			
	Week No	Soil Depth (Cm)				Soil Depth (Cm)			
		0	5	15	30	0	5	15	30
1	26	34.0	34.0	34.0	34.0	52.0	50.0	49.0	41.0
2	27	34.0	33.0	34.0	34.0	52.0	49.5	42.0	42.0
3.	28	34.0	33.0	34.0	34.0	57.0	53.0	47.6	47.0
4.	29	29.0	28.5	29.0	34.0	42.0	39.0	36.0	35.0
5.	30	30.0	30.0	30.0	36.5	46.0	43.0	40.0	38.5
6.	31	32.5	31.0	31.5	38.0	53.0	48.0	42.5	40.0
7.	32	30.0	29.0	30.0	36.5	50.0	46.0	42.0	39.0
8.	33	31.0	30.0	32.0	37.0	47.0	44.5	41.0	39.0
9.	34	32.0	32.0	34.0	39.0	54.0	50.0	43.0	41.0
10.	35	31.0	30.0	31.0	39.0	54.0	57.0	42.0	40.0
11.	36	30.5	29.5	31.0	39.0	57.0	52.0	42.5	40.0
12	37	30.0	29.0	30.5	38.0	56.0	52.0	43.0	40.0
13	38	31.0	31.0	32.0	39.0	60.0	54.5	44.0	41.0
14	39	29.5	28.5	31.0	38.0	51.0	46.0	40.0	38.5
15	40	28.0	27.0	30.0	36.5	54.5	48.0	40.0	38.0

Table 6: Weekly mean Soil temperature (°C) of kharif 2014, 2015 and 2016.

The highest temperature at about mid-day was at the boundary between the crop canopy and air might have been that only a small portion of light energy absorbed by green plant, is used for potential processes, most of it goes into heat and much of which is eventually lost from plant into atmosphere [9]. The amount of increase in soil temperature during the day was higher than air temperature, so that the rise in soil temperature contributes to energy stored in soil, used in evaporation and enough for the growth and development of micro-flora and fauna of soil. The soil temperature in the morning show a decreasing trend from surface to 5 cm soil depth and then reversed trend from 5 cm to 30 cm depth of soil. In the noon it had the highest value on the soil surface and then shows decreasing trend. It might be due to the heat transfer from the upper soil strata to the lower, either by conduction or conversion [10]. The soil temperature in the noon at surface and 5 cm depth has been higher than the air temperature. It might be due to transfer of heat energy from air to soil during the day. The amount of increase in soil temperature during the day had been higher to atmospheric temperature so that the rise in soil temperature contributes to energy stored in the soil and used in evaporation and also enough for the growth and development of micro flora and fauna of soil.

Conclusion

In spite of many advances in agricultural technology in recent times, agricultural production still depends upon agro climatic (microclimate and macroclimatic) parameters and to a considerable extent. In recent times all over the world pressure has been increasing on usable land in order to satisfy the overgrowing demand for food and fodder, to face this situation scientist are exploring both the waste land and best crop orientation for these areas. Agro-ecosystem studies are of economic and ecological importance and useful for development of crops. It is of immense importance not only in raising crop but in taking its high yield too. Therefore, knowledge of the impact of these parameters would be a very vital in planning agro-ecosystem studies which is no doubt crucial for arid zone farming.

The findings of present study will help to understand that how microclimatic factors such as Soil temperature, Air temperature, Relative humidity and Net radiations etc. also could make dramatic changes in the final yield in spite of macroclimatic factors. Above study will no doubt help researchers to understand the impact of microclimatic factors on cropping pattern so that a basic hypothesis could be generate for arid zone farming specially which lies in extreme climates, it also reveals that study of agro-climatic parameters (microclimate) is of immense importance in context to arid zone farming and also helps to understand the phenomenon of improving the yield of particular crop. Finally it can be concluded that cropping success in rain fed or arid region is outcome of both microclimatic and macro climatic factors and both plays significant role to obtain optimum yield.

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