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Computation of Heat Use Efficiency and Radiation Use Efficiency for different Groundnut (*Arachis hypogaea* L.) Varieties in Middle Gujarat

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AUTHORS CONTRIBUTION

S. T. YADAV :
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ABSTRACT

A field experiment was conducted on heat use efficiency (HUE) and radiation use efficiency (RUE) for groundnut in middle Gujarat at Agronomy farm, B.A. College of Agriculture, Anand, AAU, Anand (Gujarat) during 2019 and 2020. Results analysis of three different dates of sowing revealed that first onset of monsoon recorded higher HUE (1.02 kg ha^{-1} °C day and 0.91 kg ha^{-1} °C day, respectively) as compared to second 10 days after onset of monsoon (0.82 kg ha^{-1} °C day and 0.84 kg ha^{-1} °C day) and third 20 days after onset of monsoon (0.72 kg ha^{-1} °C day and 0.72 kg ha^{-1} °C day) that attributed to higher pod yield. Variety, GG 20 recorded higher HUE (0.91 kg ha^{-1} °C and 0.87 kg ha^{-1} °C day) and higher pod yield followed by GJG 34 and TAG 37A . In case of HUE biomass, first onset of monsoon sowing recorded higher biomass (2.76 kg ha^{-1} °C day and 2.24 kg ha^{-1} °C day, respectively) compared to other dates of sowing. Among the varieties, GG 20 (2.36 kg ha^{-1} °C day and 2.05 kg ha^{-1} °C day) recorded higher biomass followed by GJG 34 and TAG 37A. Mean radiation use efficiency of groundnut pod was 1.28 g MJ^{-1} with first onset of monsoon variety recorded lower RUE 1.48 g MJ^{-1} compared to other two dates of sowing. TAG 37A recorded higher RUE 1.74 g MJ^{-1} in respect with other two varieties.

Keywords : Heat use efficiency, Groundnut, Middle Gujarat, Radiation use efficiency, Yield

GROUNDNUT (*Arachis hypogaea* L.) is an important oil seed crop of tropical and subtropical regions of the world. In our country, it is one of the most important crop. Well-distributed rainfall of 500 mm during crop growth period and abundance of bright sunshine hours with relatively warm temperature is ideal. Sowing, emergence, germination, flowering, vegetative and pod development of groundnut requires well distribution of rainfall. However, well distributed rainfall ensures that the normal growth and development of the pods. Temperature in the range of 25ºC to 30ºC is optimum for plant development. Being a C3 crop, higher temperatures may affect its productivity and to some extent its distribution (Weiss, 2000). In India, groundnut occupies an area of 5.5 m ha producing 9.6 Mt with a productivity of 1750 kg ha^{-1} (Shwetha *et al.* 2017). It is mainly grown in rainy season and about 80 per cent of the total groundnut production under this season. Gujarat stands first rank in area and production (Anonymous, 2012). It occupies 1.95 million hectares (28.93 per cent) of the total area of the country producing 3.39 million tonnes (42.43 per cent) of the total production of the country with a productivity of 1777 kg ha^{-1}. Owing to vagaries of monsoon yield of groundnut fluctuations are more in year to year (Anonymous, 2010). It is predominantly grown in monsoon (June-October) season and Junagadh is the most productive among all the districts in Gujarat (Sahu *et al.,* 2004). In Gujarat, Anand district occupies area about 7000 ha, production 1200 MT and yield 1701 kg ha^{-1} of groundnut (Anonymous, 2011).

Heat use efficiency (HUE) and radiation use efficiency (RUE) is used effectively for the prediction of growth and yield of crops. Growing degree days is an

independent variable to describe plant growth and development of crop. It can be used as a tool for characterizing thermal responses in crops. Knowledge of accumulated GDD can provide an estimate of development stage as well as crop harvest date (Roy *et al*., 2005). The occurrence of different phenological stages during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (Murthy, 1986). Although, the Heat use efficiency (HUE) and radiation use efficiency (RUE) has been used widely to evaluate the performance of many crops under different climatic situations, studies on heat units and RUE under rainfed condition are lacking. Keeping in view the above, the present investigation was carried out to study the heat use efficiency and radiation use efficiency for groundnut to identify the suitable date of sowing for groundnut in middle Gujarat region.

Material and Methods

The field experiment was conducted during *kharif* season during 2019 and 2020 at Anand Agricultural University, Anand, Gujarat, India. Located at an latitude of 22° 35' N and longitude of 72° 55' E and at an altitude of 45.1M above the mean sea level. The soils are sandy loam soil in texture with field capacity of 15.4 to 15.8 bar at different depth. Bulk density was 1.52 g cm^{-3} to 1.55 g cm^{-3} in the 15 to 45 cm layer at the experimental site. The treatments consists of three dates of sowing *viz*; first date of sowing : onset of monsoon, second date of sowing: 10 days after onset of monsoon and third date of sowing : 20 days after onset of monsoon with three varieties GG 20, GJG 34 and TAG 37A. The experiment was replicated four times in randomized block design. The crop was sown at a distance of 30 cm x 10 cm. Approximately 60 mm as heavy irrigation and 40 mm for light irrigation was given to each plot as a life saving irrigations. The meteorological data were collected from the Agrometeorological observatory which is adjacent to the experimental site. All the package of practices was followed as per recommended. The statistical analysis was carried out by using 'Analysis of variance techniques'. The significance was tested by 'F' value at 5 per cent level of significance. The value of critical difference (C.D.) for examining treatment means for their significance was done at 5 per cent level. The growing degree days were determined on the basis of base temperature 10°C (Ghadekar, 2011) for the groundnut crop. Heat use efficiency and radiation use efficiency was computed using the weather parameters and crop growth data with the pertinent prescribed formula.

Meteorological Observations

Daily weather data for maximum and minimum temperature (°C), morning and afternoon relative humidity (%), solar radiation (MJ /m^2 /day), wind speed (m/s) and rainfall (mm) during crop growing period for Anand were recorded from the agrometeorological observatory, Department of Agricultural Meteorology, B.A. College of Agriculture, Anand Agricultural University, Anand.

Growing Degree Days (GDD)

Growing degree days (GDD) is an arithmetic accumulation of daily mean temperature above certain threshold temperature (base temperature) and is calculated as :

$$GDD\ (°C) = \left\langle \frac{Tmax + Tmin}{2} \right\rangle - T_{base}$$

where,

Tmax : Daily maximum temperature (^oC) during a day

Tmin : Daily minimum temperature (^oC) during a day

T_{base} : Base temperature 10^oC

Heat Use Efficiency (HUE)

Heat use efficiency (HUE) is also computed by using following formula :

$$\text{Heat use efficiency (kg ha}^{-1}\ °C) = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Accumulated heat units (°C day)}}$$

Radiation Use Efficiency

Radiation use efficiency (RUE) is computed as the ratio of sum of biological yield to the sum of intercepted PAR by the crop plants (Sinclair and Muchow, 1999).

$$RUE\ (g\ MJ\ m^{-2}) = \frac{BY}{IPAR}$$

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Where,

RUE = Radiation use efficiency

BY = Biological yield of groundnut

IPAR = Intercepted photosynthetic active radiation

Results and Discussion

Air Temperature

The result revealed that crop experienced highest maximum temperature of 36.0°C during emergence to vegetative stage in 2019 while, it was 36.5°C during 2020 in crop season (Fig.1). The average maximum temperature showed more or less similar trend upto flowering stage and after it decreases upto to physiological maturity and harvesting of crop during 2019. While, during 2020, it was higher upto physiological maturity and it decreased later at harvesting. It was observed that the maximum temperature was relatively lower than the normal from flowering to harvesting during 2019 and 2020.

The lowest minimum temperature of 17.8°C and 15.20°C recorded at physiological maturity to harvesting phase during 2019 and 2020, respectively (Fig. 2). During establishment stage (26th - 27th SMW),

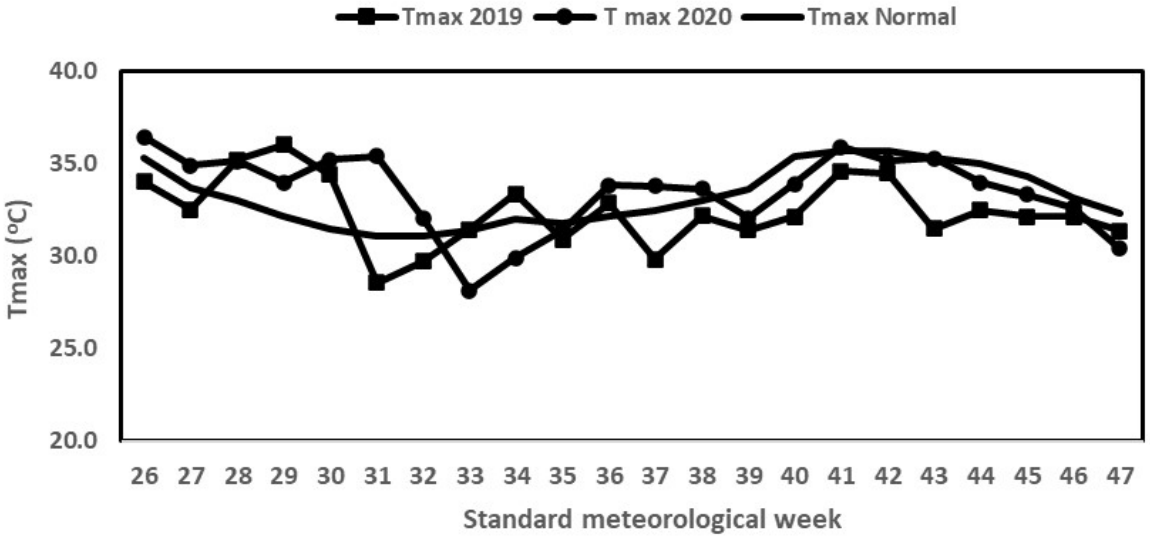

Fig. 1: Maximum temperature (°C) during crop growing season of 2019 and 2020

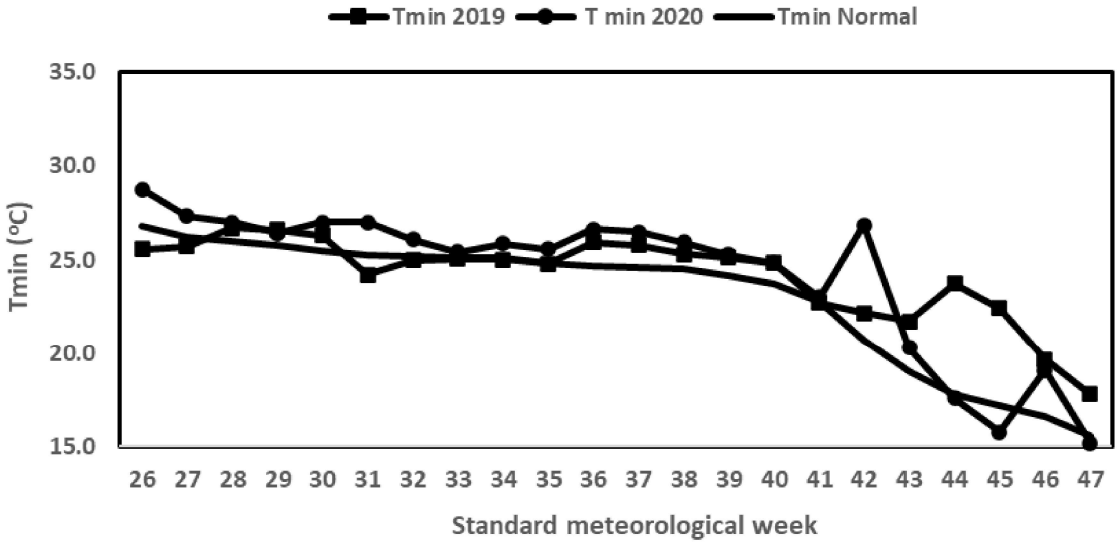

Fig. 2: Minimum temperature (°C) during crop growing season of 2019 and 2020

minimum temperature was lower than normal in 2019 whlie, in 2020, it was higher than the normal. The minimum temperature showed increasing trends upto physiological maturity in both years. The minimum temperature was higher continuously upto pod development and it was lower at harvesting stage in 2020 as compared 2019. The variability in mean minimum temperature was lower during 2019 as compared to 2020. Minimum temperature was relatively higher than the normal from flowering to harvest during both the years.

Growing Degree Days (GDD)

The accumulated GDD of first onset of monsoon sowing was 2145 °C day and 1906 °C day, second 10 days after onset of monsoon was 2368 °C and 1895 °C day and third 20 days after onset of monsoon was 2264 °C day and 1906 °C day during 2019 and 2020, respectively (Table 1). The accumulated GDD from sowing to physiological maturity was highest (2368 °C days) in first 10 days after onset of monsoon compared to other dates of sowing. It was noticed that duration of crop growth period or number of days taken to physiological maturity was higher in second 10 days after onset of monsoon in 2019. The accumulated GDD followed an increasing trend of GDD values from flower initiation to maturity. The highest accumulated GDD was observed with emergence, flowering and initiation of pod filling stage under first date of sowing followed by second and third date of sowing during both the years Guled (2013). Among the varieties, accumulation of GDD from sowing to physiological maturity were 2254 °C days and 1951 °C days during 2019 and 2020, respectively.

Heat Use Efficiency (HUE) for Pod Yield and Biomass

HUE of pod decreased with decrease in the pod yield and biomass of groundnut crop during 2019 and 2020. Results showed that first onset of monsoon recorded higher HUE (1.02 kg ha^{-1} °C day - 0.91 kg ha^{-1} °C day) as compared to second 10 days after onset of monsoon (0.82 - 0.84 kg ha^{-1} °C day) and 20 days after onset of monsoon (0.72 - 0.72 kg ha^{-1} °C day) which could be attributed to higher pod yield. In case of crop sown at first onset of monsoon, rainfall, soil moisture and mean temperature favorable during crop growing period showed significantly higher pod yield. The lowest HUE for pod yield in third sowing might be due to the lowest pod yield. The results were in conformity with Meena *et. al*. (2015). In case of varieties, GG 20 recorded higher HUE (0.91 kg ha^{-1} °C - 0.87 kg ha^{-1} °C day) and higher pod yield followed by GJG 34 (0.85 kg ha^{-1} °C - 0.83 kg ha^{-1} °C day) and TAG 37A (0.79 kg ha^{-1} °C - 0.77 kg ha^{-1} °C

TABLE 1

Phenophase wise accumulated degree day (°C days) of groundnut during 2019 and 2020

Phenophase	Emergence °C days		Flowering °C days		Initiation of pod filling°C days		Peak LAI °C days		Maturity °C days		Harvesting °C days	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Date of sowings												
Onset of monsoon	160	155	694	648	1435	1433	1607	1646	2125	1891	2145	1906
10 days after onset of monsoon	147	124	636	583	1448	1398	1636	1608	2351	1881	2368	1895
20 days after onset of monsoon	159	155	599	648	1182	1433	1596	1646	2245	1891	2264	1906
Varieties												
GG 20	151	140	637	637	1355	1424	1607	1634	2237	1937	2254	1951
GJG 34	164	140	655	637	1367	1431	1607	1634	2237	1937	2254	1951
TG 37A	151	147	637	617	1343	1405	1607	1634	2237	1937	2254	1951

*LAI : Leaf Area Index

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day). Hence, it showed that higher HUE and highest pod yield is observed in variety GG 20 as compared to other varieties. The lowest HUE for pod yield in variety TAG 37A might be due to the lowest pod yield. These results in agreement with the findings by Kingra and Kaur (2012). Meena *et. al.,* (2015) was showed that higher heat unit efficiency was observed in HNG 10 variety compared to TG 37A variety (Table 2).

The HUE of biomass was found more in 2019 as compared to 2020. Among the dates of sowing, first onset of monsoon sowing recorded higher HUE (2.76 kg ha^{-1} °C day to 2.24 kg ha^{-1} °C day) compared to second 10 days after onset of monsoon sowing (2.00 kg ha^{-1} °C day to 1.92 kg ha^{-1} °C day) and third 20 days after onset of monsoon sowing (1.98 kg ha^{-1} °C day to 1.62 kg ha^{-1} °C day) which could be attributed to higher biomass. The lowest HUE and lowest biomass was found in third, date of sowing. Similar Results were recorded by Meena *et. al.,* (2015). Kingra and Kaur (2012) who reported that late sown crop (July) availed less growing degree-days and accumulated less dry matter than the earlier sown (June) crop, thus indicating a decrease in dry matter and heat use efficiency. Among the varieties, GG 20 showed recorded higher HUE (2.36 kg ha^{-1} °C day and 2.05 kg ha^{-1} °C day) followed by GJG 34 (2.25 kg ha^{-1} °C day and 1.94 kg ha^{-1} °C day) and TAG 37A (2.08 kg ha^{-1} °C day and 1.81 kg ha^{-1} °C day). The lowest HUE in TAG 37A might be due to the lowest biomass (Table 2).

Radiation Use Efficiency (RUE) for Pod Yield and Biomass

RUE of pod yield under the dates of sowing, onset of monsoon sowing recorded lower RUE (1.13 g MJ^{-1}) compared to second date of sowing (1.74 g MJ^{-1}) and third date of sowing (1.93 g MJ^{-1}). RUE of pod yield increasing with the dates of sowing of groundnut crop was delay in sowing during 2019 and 2020. The higher RUE for pod yield was observed during year 2019 compared to 2020. Similar findings were reported by Guled P.M. (2013). Among the varieties, TAG 37A observed higher RUE (1.74 g MJ^{-1}) compared to other varieties during 2019 and 2020. Maximum RUE of biomass recorded in 10 days after onset of monsoon sowing (0.73 g MJ^{-1}) during 2019 compared to other dates of sowings (Table 3). The results revealed that RUE of for biomass under the different varieties, GG 20 found more RUE (0.64 g MJ^{-1}) compared to GJG 34 and TAG 37A during year 2019 (Table 3).

TABLE 2

Heat use efficiency pods and biomass yield of different groundnut varieties as influenced by different sowing dates

Treatments	Heat use efficiency (kg ha^{-1}°C^{-1} day)											
	Pod yield						Biomass					
	GDD		HTU		PTU		GDD		HTU		PTU	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Dates of sowing												
Onset of monsoon	1.02	0.91	0.23	0.18	0.08	0.08	2.76	2.24	0.62	0.39	0.22	0.17
10 days after onset of monsoon	0.82	0.84	0.17	0.18	0.07	0.08	2.00	1.92	0.41	0.34	0.16	0.15
20 days after onset of monsoon	0.72	0.72	0.15	0.16	0.06	0.08	1.98	1.62	0.42	0.26	0.16	0.13
Varieties												
GG 20	0.91	0.87	0.19	0.15	0.07	0.07	2.36	2.05	0.51	0.35	0.19	0.16
GJG 34	0.85	0.83	0.18	0.14	0.07	0.07	2.25	1.94	0.48	0.33	0.18	0.15
TG 37A	0.79	0.77	0.17	0.13	0.06	0.06	2.08	1.81	0.45	0.31	0.17	0.14

TABLE 3

Radiation use efficiency of different varieties of groundnut pods and biomass yield as influenced by different sowing dates

Treatments	Radiation use efficiency (g MJ^{-1})					
	Pod yield			Biomass		
	2019	2020	Mean	2019	2020	Mean
Onset of monsoon	1.13	1.42	1.28	0.42	0.58	0.50
10 days after onset of monsoon	1.74	1.44	1.59	0.73	0.60	0.67
20 days after onset of monsoon	1.94	1.66	1.80	0.50	0.74	0.62
Varieties						
GG 20	1.58	1.38	1.48	0.64	0.59	0.62
GJG 34	1.49	1.51	1.50	0.57	0.63	0.60
TG 37A	1.74	1.63	1.59	0.44	0.70	0.57

Groundnut Pod and Biomass Yield

Significantly high pod yield (2176 kg ha^{-1} and 1862 kg ha^{-1}) and biomass (5909 kg ha^{-1} and 4765 kg ha^{-1}) was recorded during both years under onset of monsoon (first date of sowing) which was statistically on par with 10 days after onset of monsoon (second date of sowing) and significantly higher than the 20 days after onset of monsoon (third date of sowing). Guled *et. al.* (2013) recorded the highest yield (2244 kg ha^{-1}) in the onset of monsoon as compared to other dates of sowing. Among the varieties on pod yield was significantly higher (2043 kg ha^{-1} and 1701 kg ha^{-1}) under variety GG 20 over varieties GJG 34 and TAG 37A (Table 4).

It could be concluded from these results that the varieties and sowing dates had significant influence on yield of groundnut. Variety GG 20 recorded significantly higher pod and biomass yield of groundnut compared to other varieties. GG 20 variety during first onset of monsoon particularly in middle

TABLE 4

Pod and biomass yield of different groundnut varieties under different sowing dates

Treatments	Pod yield (kg ha^{-1})		Mean	Biomass (kg ha^{-1})		Mean
	2019	2020		2019	2020	
Date of sowing						
Onset of monsoon	2176	1862	2019	5909	4765	5337
10 days after onset of monsoon	1937	1592	1765	4739	4193	4466
20 days after onset of monsoon	1614	1369	1492	4463	3519	3991
Variety						
GG 20	2043	1701	1872	1872	5341	3607
GJG 34	1915	1612	1764	1763	5071	3417
TG 37A	1769	1511	1640	1640	4699	3170
SEm ±	46.7	47.9	47.3	33.4	43.4	38.4
CD at 5%	135.3	138.7	137.0	95.1	125.6	110.4
CV %	8.5	10.3	9.4	9.3	3.0	6.2

Gujarat agro climatic zone could be considered as thermo tolerant variety for under middle Gujarat agro climatic zone.

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