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Thermal Indices Requirement of Brinjal Varieties (*Solanum melongena* L.) under Different Planting Windows

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out at Faculty of Agriculture Department of Agricultural Meteorology Farm, Centre for Advanced Agricultural Meteorology, College of Agriculture, Pune during Kharif seasons of 2014 and 2015.The experiment was laid out in split plot design with three replications.The treatment comprised of three brinjal hybrids viz.,V1:Phule Arjun, V2: Krishna, V3: Panchganaga as main plot and four planting windows viz., P1: 31st MW (30 July-5 August), P2: 32ndMW (6-12August), P3:33rdMW (13-19 August) and P4: 34thMW (20-26 August) as sub plot treatments.

Cumulative GDD, HTU and PTU at the end of each growth stages showed that numerically higher requirement was observed in hy.Phule Arjun over hy.Krishana and hy.Panchganaga hybrids during both year 2014 and 2015 experimentation period. Whereas, the lowest canopy temperature was found in hy.Phule Arjun (29.0 ^{0}C) than rest of the brinjal hybrids. Canopy reflected PAR and transmitted PAR was higher in (191.54 and 188.62 µ mol m-^{2}s^{-1}) Panchganaga hybrids among the

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brinjal hybrids. Heat unit requirement or GDD has been used for characterizing the thermal response in brinjal crop. GDD for entire crop growing period decreased with subsequent delay in planting. HTU and PTU were also decreased during later planting windows condition. GDD in different stages in that emergence (59.6 and 72.3), vegetative growth (481 and 478), 50% flowering (575 and 568), first harvesting (681 and 645), last harvesting (1178 and 1183) was observed in hybrid Phule Arjun during 2014 and 2015, respectively. Lower GDD was observed in hy.Panchaganaga during 2014 and 2015, respectively.

The highest HTU observed in 31st MW planting windows in hybrids Phule Arjun (5376 and 9190.4).This was followed by hy.krishna and Panchganaga (5370 and 9086) during 2014 and 2015, respectively. Highest HTU was observed in 31st MW in hybrids Phule Arjun followed by hy.krishna and lower in panchganga.

Keywords: King of vegetables; egg plant; economic threshold level; Rabi season; changing climatic conditions.

1. INTRODUCTION

Brinjal or egg plant (*Solanum melongena* Linnaeus) is from Solanaceae family belonging to genus *Solanum* and known as "King of vegetables" [1,2]. It is a native of India. It is an important vegetable crop grown throughout the country all the year round. Brinjal crop requires a long warm climate for its growth. Temperatures ranging between 25-32^{0}C are suitable for its cultivation (Arya, 2018). It does not prefer cool or frosty weather and requires silt loam to clay loam soil. Determination of optimum planting windows is considered an important effort to have optimum yields and keep insect pest damage below economic threshold level (ETL) both quantitative and qualitative traits of crops depend on planting on the proper windows and growing season [3]. In India higher brinjal quality Prolonged periods of low or high temperatures or sudden change in them adversely affect the insect development [4]. Different levels of humidity and rainfall, likewise, increase or reduce the population of certain insect pest species [5]. These factors affect the life cycle, propagation, and outbreaks of insects to such an extent that they are either compelled to adapt themselves to the changing climatic conditions and are extensively cultivated in Kharif and Rabi season. Timings of the management activities are crucial for the implementation of pest management tactics and consuming higher doses of pesticides. High yield and quality of vegetables depends on high seed quality of improved cultivars, in addition to the optimum cultural practices. Information on crop, its stages and the week by week weather during the crop season is essential for proper management of agriculture and better crop yield.

2. MATRIALS AND METHODS

The field experiment was conducted at Department of Agricultural Meteorology Farm, College of Agriculture, Pune during kharif seasons of 2014 and 2015. The experiment was conducted in a split plot design with three replications. The treatments were allotted randomly to each replication by keeping the gross plot size 4.5m x 3.75 m2 and net plot size 2.7 m x 2.7 m2with 90 x 75 cm spacing. There were twelve treatment combinations. The experiment was laid out in split plot design with three replications. The treatment comprised of three brinjal hybrids viz., V1: Phule Arjun V2: Krishna, V3: Panchganga as main plot and four planting windows viz., P1: 31MW (30 July-3Aug), P2:32nd MW (6 Aug- 12 Aug),P3: 33rd MW (13Aug- 19 Aug) P4: 34th MW (20 Aug- 26 Aug) as sub plot treatments**.**

Light use efficiency was determined as:

$$\text{LUE} = \frac{\text{Amount of dry matter produced (g m} - 2)}{\text{Amount of cumulative PAR absorbed (MJ m} - 2)}$$

Incident, transmitted and reflected radiation were measured with Line Quantum Sensor (LI COR) and Data logger (LI COR 1000). Radiation was recorded in terms of µmol $m^{-2}s^{-1}$. But for estimation of LUE cumulating absorbed radiation was first estimated with the help of above equations and then converted from µmol $m^{-2}s^{-1}$ to MJ m^{-2} by multiplying factor of 0.0188.

2.1 Growing Degree Days (GDD)

Temperature is a major environmental factor that determines the rate of plant development. The temperature requirement and range of optimum temperature varied with species and genotype.

The thermal response of genotype can be quantified by using the heat unit or thermal time concept. There is high probability of successfully predicting the development of brinjal by heat unit. Thermal time or growing degree days were calculated according to the equation.

$$GDD = [(T_{max.} + T_{min.})/2 – Tb]$$

Where,

GDD = Growing degree days
$T_{max.}$ = Daily maximum temperature of i^{th} day (^{0}C)
$T_{min.}$ = Daily minimum temperature of i^{th} day (^{0}C)
Tb = Base temperature of brinjal (11^{0}C)

2.2 Photo-thermal Units (PTU)

Photo-thermal units were determined by GDD multiplying with maximum possible sunshine hours (N).

Determination of maximum possible sunshine hours:

Maximum possible sunshine hours was calculated by using following equation
N=COS(RADIANS((COS(RADIANS(((A91172)*2 *180)/365)))*23.5))

2.3 Helio Thermal Units (HTU)

Heliothermal units for various growth stages are calculated by the formula given. HTU = GDD x Bright sunshine hours

3. RESULTS AND DISCUSSION

3.1 Radiation Use Efficiency (RUE)

The data regarding radiation use efficiency as influenced periodically by different hybrids and planting windows are presented in Table 1.

3.2 Effect of Hybrids

The values of Radiation use efficiency were recorded higher (2.25 and 2.43 g $MJ^{-1}m^{-2}$) in both the years *i.e.* 2014 and 2015 in hybrids Phule Arjun than other two hybrids *viz.,* Krishna and Panchganaga. The lowest RUE values (1.85 and 1.86 g MJ^{-1} m^{-2}) in both the years i.e. 2014 and 2015 were recorded in hybrids Panchaganga.

3.3 Effect of Planting Windows

The planting windows at 31st MW recorded higher values of (2.28 and 2.46 g $MJ^{-1}m^{-2}$) radiation use efficiency and gradually decreased with delayed planting. The radiation use efficiency increased periodically from 28 DAT to 70 DAT. After 70 DAT, radiation use efficiency was declined up to final harvest. The planting windows at 34th MW recorded the lowest values of (2.02 and 1.92 g $MJ^{-1}m^{-2}$ radiation use efficiency than rest of the planting windows. The high LAI persistence and PAR interception, coinciding with the vegetative phase, appeared to be mainly responsible for the increased yield in early planting. Radiation use efficiency decreased as planting was delayed, but did not have much effect on DM accumulation in various phases nor on final yields. These results are in conformity with the findings of Okusanya [6], Zieslin and Tsujita (1990).

3.4 Determination of Growing Degree Days (GDD)

Data regarding phenophases wise growing degree days (GDD) and total growing degree days availed by different treatments, Hybrids and planting windows are presented in Table below for the years of 2014 and 2015. The accumulated growing degree days to reach various growth stages showed variation among the different treatments, hybrids and planting windows. The accumulated growing degree days were reasonably higher during reproductive stage as compared to vegetative stage [7].

3.5 Effect of Hybrids

The GDD in different hybrids varied from 35.41 to 72.3^{0}C for emergence, 444.48 to 481.76^{0}C days for vegetative growth, 512 to 575^{0}C for 50 % flowering, 568.65 to 681.66^{0}C days for first fruit setting and 1154.11^{0}C to 1183.7^{0}C days for final harvest. The highest values of GDD were recorded in hybrids Phule Arjun and the lowest values of GDD were recorded in hybrids Panchganaga.

Table 1. Radiation Use Efficiency ($gmMJ^{-1}m^{-2}$) of brinjal influenced periodically different by treatments in 2014 and 2015

Treatment	14 DAT		28 DAT		42 DAT		56 DAT		70 DAT		84 DAT		120 DAT		At final harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
A)Hybrids(H)																
V_1 :Phule Arjun	0.18	0.18	0.51	0.49	0.50	0.48	2.25	2.43	2.39	2.25	2.12	1.98	2.16	2.12	1.85	1.76
V_2: Krishna	0.10	0.12	0.21	0.24	0.41	0.41	2.18	2.33	2.27	2.14	1.94	1.82	1.98	1.94	1.78	1.69
V_3: Panchganga	0.06	0.08	0.15	0.18	0.35	0.35	2.13	2.26	2.15	2.03	1.82	1.72	1.86	1.82	1.70	1.64
B)Planting windows(D)																
P_1:31 MW (30 July– 5 August)	0.12	0.13	0.32	0.34	0.46	0.45	2.28	2.46	2.35	2.21	2.01	1.85	2.05	1.95	1.83	1.76
P_2:32 MW (6August - 12August)	0.12	0.13	0.30	0.31	0.44	0.43	2.23	2.41	2.25	2.07	1.93	1.80	1.97	1.87	1.77	1.70
P_3:33MW (13August - 19 August)	0.12	0.13	0.29	0.30	0.42	0.41	2.12	2.29	2.26	2.11	1.91	1.79	1.95	1.85	1.76	1.68
P_4:34(20 - 26August)	0.09	0.11	0.26	0.27	0.37	0.37	2.12	2.18	2.22	2.19	1.98	1.91	2.02	1.92	1.74	1.64
General mean	0.11	0.13	0.29	0.31	0.42	0.41	2.19	2.34	2.27	2.14	1.96	1.84	2.00	1.90	1.78	1.70

Table 2. Cumulative growing degree days (GDD) of brinjal as influenced stage wise different by treatments in 2014 and 2015

Treatment	EM		VG		50% FL		First FR		At final harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
A) Hybrids(H)										
V_1 :Phule Arjun	59.6	72.3	481.76	478.3	575.5	568.65	681.66	645.7	1178.43	1183.7
V_2: Krishna	47.56	47.63	470.28	467.48	552.18	535.01	623.38	602.55	1166.28	1170.42
V_3: Panchganga	35.41	46.13	447.2	444.48	540.26	512.55	599.13	568.65	1154.11	1157.22
B) Planting Windows(D)										
P_1:31 MW (30 July– 5 August)	53.75	61	46.45	484.6	525.5	597.55	631.8	658.6	1135.55	1183.2
P_2:32 MW (6August 12August)	45.25	59.4	453.3	464.9	530.85	554.53	624.3	641.35	1143.25	1161.85
P_3:33MW (13August –19 August)	39.1	50.4	457.5	471.85	526.45	543.25	616.4	621	1128.95	1152.1
P_4:34M(20- 26 August)	37.85	38.65	452.2	469.65	512.45	539.05	611.05	611.4	1129.65	1143.4
General mean	45.50	53.64	401.24	468.75	537.60	550.08	626.82	621.32	1148.03	1164.56

Table 3. Cumulative Heliothermal units (HTU) of brinjal as influenced stage wise by different treatments in 2014 and 2015

Treatment	EM		VG		50% FL		First FR		At final harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
A) Hybrids(H)										
V_1 :Phule Arjun	249.97	351.86	1544.45	3539.83	1893.69	4357.69	2142.17	4993.37	5376.94	9190.09
V_2: Krishna	161.48	195.88	1450.24	3247.27	1698.43	4047.63	1893.69	4555.53	5282.36	9286.87
V_3: Panchganga	15188.	271.31	1508.33	3435.54	1763.81	4164.83	2014.88	4902.32	5370.95	9086.14
B) Planting Windows										
P_1:31 MW (30 July– 5 August)	251.24	34.785	1628.53	1982.23	1930.74	2767.46	2333.667	4904.23	4899.03	9970.4
P_2:32 MW (6August 12August)	145.055	344.27	1277.85	3927.96	1673.78	4770.45	1852.04	5303.45	5027.52	10154.52
P_3:33MW (13August –19 August)	93.96	411.98	1553.68	4044.66	1684.69	4629.4	1915.68	5318.79	5587.88	10145.44
P_4:34MW(20-26August)	184.64	100.255	1353.01	3658.41	1695.25	4177.76	2058.23	3223.48	5989.48	6877.1
General mean	178.26	244.33	1473.73	3405.13	1762.91	4130.75	2030.05	4743.02	5362.02	9244.37

Table 4. Heat Use Efficiency ($gmm^{-2}day^{-1}$) of brinjal influenced periodically by different treatments in 2014 and 2015

Treatment	14 DAT		28 DAT		42 DAT		56 DAT		70 DAT		84 DAT		120 DAT		At final harvest	
	2014	2015	2014	2015	2014	2015	2014	2014	2015	2015	2014	2015	2014	2015	2014	2015
A)Hybrids (H)																
V_1 :Phule Arjun	0.01	0.02	0.36	0.36	0.48	0.50	1.10	1.09	1.48	1.48	1.80	1.83	1.84	1.85	1.74	1.76
V_2: Krishna	0.00	0.01	0.10	0.13	0.24	0.27	0.82	0.84	1.19	1.16	1.47	1.50	1.56	1.56	1.45	1.44
V_3: Panchganga	0.01	0.01	0.13	0.16	0.29	0.32	0.87	0.91	1.26	1.26	1.58	1.61	1.66	1.67	1.56	1.55
B)Planting windows(D)																
P_1:31 MW (30 July– 5 August)	0.01	0.01	0.23	0.25	0.39	0.42	1.04	1.02	1.40	1.39	1.70	1.71	1.83	1.79	1.68	1.68
P_2:32 MW (6August 12August)	0.01	0.01	0.20	0.22	0.35	0.38	0.95	0.96	1.33	1.31	1.61	1.62	1.72	1.71	1.59	1.59
P_3:33MW (13Augu2st –19August)	0.01	0.01	0.19	0.21	0.33	0.35	0.92	0.93	1.30	1.28	1.57	1.58	1.67	1.66	1.56	1.55
P_4:34M (20August -26August)	0.01	0.01	0.17	0.19	0.29	0.31	0.86	0.87	1.21	1.24	1.53	1.54	1.58	1.60	1.48	1.51
General mean	0.01	0.01	0.20	0.22	0.34	0.36	0.94	0.94	1.31	1.30	1.60	1.61	1.69	1.69	1.58	1.58

3.6 Effect of Planting Windows

The GDD in different planting windows varied from 37.85 to 61^{0}C for emergence, 452.2 to 484.6^{0}C days for vegetative growth, 512.45 to 597.55^{0}C for 50 % flowering, 611.05 to 658.66^{0}C days for first fruit setting and 1128.85^{0}C to 1183.2^{0}C days for final harvest. The highest values of GDD were recorded in 31st MW planting windows and the lowest values of GDD were recorded in 34th MW planting windows.

3.7 Determination of Heliothermal Units (HTU)

The data regarding heliothermal units as influenced periodically by different hybrids and planting windows are presented in Table below. Total HTU required for completion of growth of brinjal crop was 9244^{0}C days.

3.8 Effect of Hybrids

The HTU in different hybrids varies from (151.88 to 351.86) units for emergence, (1450.24 to 3539.83) units for vegetative growth, (1698.43 to 4357) units for 50 % flowering, (1893.69 to 4993.37) units for first fruit setting and (5282.36 to 9286.87) units for final harvest. The highest values of HTU were recorded in hybrids Phule Arjun and the lowest values of HTU were recorded in hybrids Panchganaga.

3.9 Effect of Planting Windows

The HTU in different planting windows varies from (93.96 to 411.98) for emergence, (1277.85 to 4044.66) units for vegetative growth, (1673.78 to 4770.45) units for 50 % flowering, (1852.04 to 3223.48) units for first fruit setting and (4899.03 to 10154.52) units for final harvest. The highest values of HTU were recorded at 31st MW planting window and the lowest values of HTU were recorded at 34thMW planting window. This might be due to delayed planting completed each phenophases earlier than the late planted crop.

3.10 Heat Use Efficiency (HUE)

The data regarding heat use efficiency as influenced periodically by different hybrids and planting windows are presented in Table 3.

3.11 Effect of Hybrids

The values of heat use efficiency were recorded higher in (1.84 and1.85 gm m^{-2} day^{-1}) hybrids Phule Arjun than other two Hybrids *viz.,* Krishna and Panchganaga. The lowest heat use efficiency values were recorded in (1.66 and 1.67 gm m^{-2} day^{-1}) hybrids Panchganga.

3.12 Effect of Planting Windows

The 31thMW planting windows recorded higher values of (1.83 and 1.79 gm m^{-2} day^{-1}) heat use efficiency and gradually decreased with delayed planting. The heat use efficiency increased periodically from 28 DAT to 70 DAT. After 70 DAT, heat use efficiency was declined up to final harvest. each The planting windows at 34thMW lower values recorded (1.58 and 1.60 gm m^{-2} day^{-1}) in the heat use efficiency than rest of the planting windows.

4. CONCLUSIONS

The Phule Arjun hybrids during 31st MW planting window has recorded highest absorbed photosynthetically active radiation (1029.75 µmol m^{-2}s^{-1}) and lowest canopy reflected photosynthetically active radiation (8.14µmol m-^{2}s^{-1}).The maximum intercepted photosynthetically active radiation (86.47µ mol m^{-2}s^{-1}) was observed in Phule Arjun hybrids and incident photosynthetically active radiation (1270µ mol m-2s-1) and lowest Transmitted photosynthetically active radiation (188.96 µ mol m^{-2}s^{-1})with higher radiation use efficiency (2.43 gmMJ^{-1}m^{-2}) followed by Krishna (2.27 gmMJ^{-1}m^{-2}), Panchagnga (2.15 gm MJ^{-1}m^{-2}).The heat use efficiency was observed in Phule Arjun (1.84 gm m^{-2}day^{-1}).Whereas the lowest canopy temperature was found in hy.Phule Arjun (29.0^{0}C) than rest of the brinjal hybrids.The higher Photothermal units (GDD, HTU and PTU) were accumulated in Phule arjun it was followed by Krishna and Panchganga.

4.1 Crop Weather Relationship

Heat unit requirement or GDD has been used for characterizing the thermal response in brinjal crop. GDD for entire crop growing period decreased with subsequent delay in planting. HTU and PTU were also decreased during later planting windows condition. GDD in different stages in that emergence (59.6 and 72.3), vegetative growth (481 and 478), 50% flowering (575 and 568), first harvesting (681 and 645), last harvesting (1178 and 1183) was observed in hybrid Phule Arjun during 2014 and 2015, respectively. Lower GDD was observed in

hy.Panchaganaga during 2014 and 2015, respectively.

The highest HTU observed in 31st MW planting windows in hybrids Phule Arjun (5376 and 9190.4).This was followed by hy.krishna and Panchganaga (5370 and 9086) during 2014 and 2015, respectively. Highest HTU was observed in 31st MW in hybrids Phule Arjun followed by hy.krishna and lower in panchganga.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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