THERMAL INDICES REQUIREMENT OF *KHARIF* GROUNDNUT (*Arachis hypogaea* L.) VARIETIES UNDER DIFFERENT SOWING WINDOW IN WESTERN MAHARASHTRA, INDIA

ABSTRACT

An agro-meteorological investigation was undertaken during the *kharif* season of 2017 and 2018 at the Department of Agricultural Meteorology Farm, College of Agriculture, Pune, Maharashtra State (India). The experiment was laid out in split plot design with three replications. The treatment comprised of four varieties *viz.,* V_1: JL-501, V_2: RHRG-6083 (*Phule Unnati*), V_3: TAG-24 and V_4: JL-776 (*Phule Bharati*) and four sowing windows *viz*., S_1: 25^{rd} MW (18^{th} to 24^{th} June), S_2: 26^{th} MW (25^{th} June to 01^{st} July), S_3: 27^{th} MW (2^{nd} to 8^{th} July) and S_4: 28^{th} MW (09^{th} to 15^{th} July). Results showed that the higher GDD was observed in 26^{th} MW sowing window with variety JL-776 (1826 and 1723) and RHRG-6083 (1763 and 1690) followed by variety JL-501 and TAG-24, whereas, higher heat use efficiency (0.088 and 0.100 g/GDD) at peg formation to rapid kernel growth stage was observed under 26^{th} MW sowing window (S_2) with variety JL-776 (V_2) during 2017 and 2018, respectively. The highest HTU was observed in 26^{th} MW sowing window in variety JL-776 (8254 and 6924) and RHRG-6083 (8171 and 7074) followed by variety JL-501 and TAG-24, whereas, higher heli**o**thermal use efficiency (0.0200 and 0.0309 g/HTU) at peg formation to rapid kernel growth stage was observed under 26^{th} MW sowing window (S_2) in variety JL-776 (V_2) during 2017 and 2018, respectively. Higher PTU (4818.42 and 4890.75) was observed under 26^{th} MW sowing window (S_2) in variety JL-776 (V_2) this was followed by var. RHRG-6083, JL-501 and TAG-24 whereas, higher photothermal use efficiency (0.0284 and 0.293 g/PTU) at physiological maturity was observed under 26^{th} MW sowing window (S_2) with variety JL-776 (V_2) followed by variety RHRG-6083, JL-501 and TAG-24 during 2017 and 2018, respectively.

Key words: Growing degree days, Groundnut, Sowing windows, Heat use efficiency, Helio thermal units, Photo thermal units, Thermal indices,

1. INTRODUCTION

"Groundnut (*Arachis hypogaea* L.) is an annual legume crop, which is also known as peanut, earthnut, goobers and monkey nut. It is the 13^{th} most important food crop and 4^{th} most important oilseed crop of the world. Groundnut products are used in food stuffs, desserts, cakes, snacks, sauces and they are also rich in protein, fat, fiber and other nutrients. The non-monetary input *i.e.* optimum sowing period is a key factor which provides a better opportunity for optimum use of the available natural resources by the crop. Groundnut crop grows under a wide range of temperatures and requires a long and warm growing season. It requires 16 ^{o}C for germination. Low temperatures retard germination and growth of plants and lengthens flowering. High temperatures of 35 ^{o}C resulted in good performance in terms of length of the stem, number of flowers and number of pods. Maximum numbers of pods are obtained at mean temperature of 23 ^{o}C. Temperature above 35 ^{o}C inhibits the growth of groundnut. Optimum mean daily temperature to grow is 30 ^{0}C and growth ceases at 15 ^{o}C" [1]. "Pod yield is significantly influenced by day length. Long days promote vegetative growth at the expense of reproductive growth and increased crop growth rate resulted in decreased partitioning of photosynthesis to pods and decreased duration of effective pod filling phase" [1]. "The occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree-days (GDD)" [2]. "Thermal time is an independent variable to describe plant development" [4]. "It can be used as a tool for characterizing thermal responses in different crops. Knowledge of accumulated GDD can provide an estimate of harvest date as well as crop development stage" [3], [5], [6] and [7]). "Heat use efficiency (HUE), i.e., efficiency of utilization of heat in terms of dry matter accumulation, depends on crop type, genetic factors and sowing time and has great practical application" [8]. "Initiation as well as duration of crop phenophase is an essential component of weather based dynamic crop growth and yield simulation models. Crop phenology can be used to specify the most appropriate date and time of specific development process. The duration of each phenophase determines the accumulation and partitioning of dry matter in different organs" [9]. "The duration of particular stage of growth was directly related to temperature and this duration of particular species could be predicted using the sum of daily air temperature" [10]. "Sowing of rainfed and irrigated crop early in the season provide favorable weather conditions for proper growth and yield of groundnut. Delay in sowing by one-week resulted in linear decrease in pod yield of groundnut. In timely sown crop, the pattern of flowering is regular with two distinct peaks of flowering, whereas, in late-sown crop erratic pattern of flowering occurs" [11]. The choice of a groundnut variety for any particular area depends on matching the variety with the length of the growing season. Groundnut varieties whose growth cycle is longer than the duration of growing season at a particular location either fail to mature or mature at a time when soil is too hard to dig the pods, therefore the investigation was carried out to assess the seasonal variation in temperature, duration of bright sunshine hours and day length at different phenophase of the groundnut crop in Pune, Maharashtra (India).

2. MATERIAL AND METHODS

2.1 Location of the Experimental Site, Soil and Climatic Condition

The field experiment was conducted for two consecutive years at Department of Agricultural Meteorology farm, College of Agriculture, Pune during *kharif,* 2017 and 2018. The geographical location of the site (Pune) was 18° 32'N, latitude; 73°51E, longitude and 557.7 m above mean sea level (MSL). The soil is medium black having depth of about 1m. The average annual rainfall of Pune is 675 mm, which is distributed from second fortnight of June to second fortnight of October. Out of total rainfall, about 75 per cent is received from June to September from south-west monsoon, while the remaining is received from north-east monsoon during October and November.

2.2 Nature of Season During Experimental Period

Daily and weekly mean meteorological data during the crop growth period (25th to 45th MW) of *kharif* 2017 and 2018 recorded in class 'A' observatory situated in the adjoining field. The daily maximum and minimum temperature during the crop growth period ranged from 34.4 and 12.7 ^{o}C during 2017 and 34.7 and 13.3 ^{o}C during 2018. The daily range of relative humidity during morning was 75-97 % and 72-97 % during the respective years while during afternoon was in the range of 26-98 %, while, it was between 16-92 % during 2017 and 2018, respectively. The bright sunshine hour's day^{-1} during crop growing period were 9.3 and 10.5 during 2017 and 2018, respectively.

During crop period, the weekly maximum and minimum temperatures varied from 27.1 to 33.4 ^{o}C and 14.1 to 23.9 ^{o}C, respectively, during 2017. It was varied from 24.2 to 37.7 ^{o}C and 13.3 to 24.6 ^{o}C respectively, during 2018. Weekly relative humidity during morning (07:30 IST) and afternoon (14.30 IST) was 93.7 and 31.1 % in 2017, whereas it was 97 and 16 % in 2018, respectively. The weekly wind velocity during the period ranged from 1.6 to 10.3 and 1.1 to 11.6 kmph during 2017 and 2018, respectively. The weekly evaporation ranged from 2.2 to 6.7 and 2.2 to 5.3 mm per day in 2017 and 2018, respectively. The weekly photoperiod *i.e.* maximum possible sunshine hours which were fixed for the particular day in a year ranged from 10.38 to 13.87.

2.3 Experimental Details

The experiment was laid out in split plot design with three replications. The treatment comprised of four varieties *viz.,* V_1: JL-501, V_2: RHRG-6083 (*Phule Unnati*), V_3: TAG-24 and V_4: JL-776 (*Phule Bharati*) as main plot and four sowing windows *viz*., S_1: 25rd MW (18th to 24th June), S_2: 26th MW (25th June to 01st July), S_3: 27th MW (2nd to 8th July) and S_4: 28th MW (09th to 15th July) as sub plot treatments. The gross and net plot size was 4.5 x 4.5 m^2 and 3.6 x 3.6 m^2, respectively. The allocation of treatments was done with random method. The certified seed of all the groundnut varieties JL-501, RHRG-6083, TAG-24 and JL-776 was procured from the Groundnut Breeder, Oilseed Research Station, Jalgaon, MPKV, Rahuri. Sowing was done as per the treatments by dibbling one kernel at each hill with 30 cm inter-row and 7.5 cm intra-row distance keeping a seed rate of 100 kgha^{-1}. The requisite plant population was maintained by thinning and gap filling where ever necessary. Urea and single super phosphate were used as source of N and P and applied as per recommended dose of Mahatma Phule Krishi Vidyapeeth, Rahuri *i.e.* 25 kg N and 50 kg P_2O_5. Seed of groundnut was inoculated with *Rhizobium* culture @ 250 g 10 kg^{-1} seed.

2.4 Thermal Units

2.4.1 Growing Degree Days (GDD)

"Temperature is a major environmental factor that determines rate of plant development. The temperature required and range of optimum temperature varies with sowing dates and available soil moisture. Thermal response of sowing dates can be quantified by using the heat unit or thermal time concept". [16] Thermal time or growing degree days was calculated according to the following equation,

$$GDD=\sum_{i=1}^{n}\frac{T\ max+T\ min}{2}-T\ base$$

where $\sum_{i=1}^{n}$ =Period in days from sowing date till the last date of harvesting

GDD = Growing degree days

$T_{max.}$ = Daily maximum temperature of day i (^{0}C)

$T_{min.}$ = Daily minimum temperature of day i (^{0}C)

Tb = Base temperature

In present study, the base temperature of groundnut was taken as 10 ^{0}C. [16] and [17]

2.4.2 Heat Use Efficiency (HUE)

Heat use efficiency (HUE) for seed and total dry matter was calculated by the formula:

$$\text{Heat use efficiency (kg/ha/}^0\text{C day)} = \frac{\text{Seed yield / Total dry matter (kg/ha)}}{\text{Accumulated heat units (}^0\text{C day)}}$$

2.4.3 Helio Thermal Units (HTU)

Heliothermal units for various growth stages are calculated by the formula given by [12].

HTU = GDD x Bright sunshine hours

2.4.4 Heliothermal Use Efficiency (HTUE)

Heliothermal use efficiency (HTUE) for seed and total dry matter was calculated by the formula:

$$\text{Heliothermal use efficiency (kg/ha/}^0\text{C day)} = \frac{\text{Seed yield / Total dry matter (kg/ha)}}{\text{Accumulated heliothermal units (}^0\text{C day)}}$$

2.4.5 Photothermal unit (PTU)

Photothermal units (PTU), the product of GDD and corresponding day length for that day were computed on daily basis as follows:

PTU = GDD × Day Length

2.4.6 Photothermal Use Efficiency (PTUE)

Photothermal use efficiency (PTUE) for seed and total dry matter are calculated by the formula:

$$\text{Photothermal use efficiency (kg/ha/}^0\text{C day)} = \frac{\text{Seed yield / Total dry matter (kg/ha)}}{\text{Accumulated photothermal units (}^0\text{C day)}}$$

3 RESULT AND DISCUSSION

3.1.1 Growing Degree Days (GDD)

It was evident from the data (Table 1) that accumulated growing degree days (GDD) varied considerably from sowing to physiological maturity of the crop. Different groundnut varieties responded differently in terms of accumulated GDD. Higher GDD was observed under 26th MW sowing window with variety JL-776 (1826 and 1723) followed by (1763 and 1690) in variety, RHRG-6083 and the lower GDD was observed in var. TAG-24 (1547 and 1487) sown at 28th MW sowing window (S_4) during 2017 and 2018, respectively, from sowing to physiological maturity. In general, the GDD values decreased when the sowing was delayed. This might be due to early maturity of crops under delayed sown condition because of higher temperature. With delayed window of sowing, accumulated GDD reduced significantly in groundnut. This was due to increase in the temperature during delayed plantings which leads to early maturity of the crop. The result of present investigation was supported by [13], [14] and [15].

3.1.2 Heat Use Efficiency (HUE) (g/GDD)

The various groundnut varieties responded differently in terms of heat use efficiency (g/GDD) at different phenophase during the growing season. The highest heat use efficiency was observed in 26th MW sowing window (S_2) in all the varieties during *kharif season*, 2017 and 2018. Heat use efficiency (g/GDD) influenced by different sowing windows and varieties in kharif groundnut, 2017 and 2018 is given in Table 2. Higher heat use efficiency (0.088 and 0.100 g/GDD) at Peg formation to rapid kernel growth stage was observed under 26th MW sowing window (S_2) in variety JL-776 (V_4) during both years of experimentation, 2017 and 2018, respectively. This was followed by var. RHRG-6083 (0.059 and 0.066). The variety TAG-24 observed lowest heat use efficiency values at 28th MW sowing window (S_4) (0.051 and 0.057 g/GDD) at rapid kernel growth to physiological maturity stage during *kharif*, 2017 and 2018.With delayed sowing window, heat use efficiency reduced significantly in groundnut. This was due to increase in the temperature during delayed sowing which accelerated the growth of the crop. The result of present investigation was supported by [13], [14] and [15].

3.1.3 Helio Thermal Unit (HTU)

Different groundnut varieties responded differently in terms of accumulated Helio thermal unit (HTU) at the time of maturity. The highest HTU was observed in 26th MW sowing window (S_2) in all the varieties. Heliothermal unit (HTU) for different genotypes varied considerably at maturity period (Table 3). Higher HTU (8254 and 6751) was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) during 2017 and 2018 this was followed by var. RHRG-6083 (8171 and 6230). The variety TAG-24 accumulated the lower HTU values was observed under 28th MW sowing window (S_4) (6639 and 5477) during 2017 and 2018, respectively. With the delayed sowing window, accumulated HTU reduced significantly in groundnut. This was due to increase in the temperature during delayed sowing which accelerated the growth of the crop. The result of present investigation was supported by [13], [14] [15], [18] and [19].

3.1.4 Heliothermal Use Efficiency (HUE) (g/HTU):

Different groundnut varieties responded differently in terms of helio thermal use efficiency (g/HTU) at different phenophase. The highest heliothermal use efficiency was observed in 26th MW sowing window (S_2) in all the varieties during *kharif*, 2017 and 2018. Heliothermal use efficiency (g/HTU) as influenced by different sowing windows and variety in *kharif* groundnut, 2017 and 2018 is given in table 4.

Heliothermal use efficiency (g/HUE) for different genotypes varied considerably at different growth stages. Higher heliothermal use efficiency (0.0200 and 0.0309 g/HTU) at Peg formation to rapid kernel growth stage was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) this was followed by var. RHRG-6083 (0.128 and 0.178) during 2017 and 2018, respectively. The variety TAG-24 observed lowest heat use efficiency values under 28th MW sowing window (S_4) (0.0152 and 0.0229 g/HTU) at rapid kernel growth to physiological maturity stage during *kharif*, 2017 and 2018.Within delayed sowing window, heliothermal use efficiency reduced significantly in groundnut. This was due to increase in the temperature during delayed sowing which accelerated the growth of the crop. The result of present investigation was supported by [13], [14] and [15].

3.1.5 Photothermal unit (PTU):

The various groundnut varieties responded differently in terms of accumulated photothermal unit at the different growth stages of groundnut. The highest PTU was observed at 26th MW sowing window (S_2) in all the varieties. Photothermal unit (PTU) for different genotypes varied considerably at different phenophase of crop (Table 5). Higher PTU (4818 and 4890) was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) at physiological maturity during both the years 2017 and 2018 this was followed by var. RHRG-6083 (4585 and 4717). The variety TAG-24 accumulated the lower PTU values was observed under 28th MW sowing window (S_4) (3614 and 3719) at physiological maturity during 2017 and 2018. With delayed sowing window, accumulated PTU reduced significantly in groundnut. This was due to increase in the temperature during delayed sowings which accelerated the growth of the crop. The result of present investigation was supported by [13], [14] and [15].

3.1.6 Photothermal Use Efficiency (g/PTU):

Different groundnut varieties responded differently in terms of photothermal use efficiency (g/PTU) at different phenophase. The highest photothermal use efficiency was observed in 26th MW sowing window (S_2) in all the varieties during *kharif*, 2017 and 2018. Photothermal use efficiency (g/HUE) for different varieties varied considerably at different growth stages (Table 6). Higher heliothermal use efficiency (0.0284 and 0.293 g/PTU) at physiological maturity was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) during 2017 and 2018 this was followed by var. RHRG-6083 (0.0228 and 0.0236) respectively. Variety TAG-24 observed lowest heat use efficiency values observed under 28th MW sowing window (S_4) (0.0193 and 0.0207 g/PTU) at physiological maturity during *kharif*, 2017 and 2018.With delayed sowing window, heliothermal use efficiency reduced significantly in groundnut. This was due to increase in the temperature during delayed sowing which accelerated the growth of the crop. The result of present investigation was supported by [13], [14] and [15].

Table 1. Cumulative growing degree days (GDD) (^{0} Days) as influenced by different sowing windows and varieties in *kharif* groundnut during 2017 and 2018

Treatment		Cumulative growing degree days (^{0} Days)													
		2017							2018						
Varieties	**Sowing window**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**
Jl-501	**S_1 - 25th MW**	129	329	449	709	881	1246	1594	122	395	525	777	964	1271	1642
	S_2 - 26th MW	157	412	547	804	1002	1336	1711	149	362	475	732	899	1225	1587
	S_3 - 27th MW	140	375	497	755	931	1296	1654	143	310	428	678	846	1179	1533
	S_4 - 28th MW	127	322	426	695	859	1244	1580	118	303	410	667	823	1184	1522
RHRG-6083	**S_1 - 25th MW**	129	374	493	769	940	1322	1707	122	410	552	822	1004	1344	1689
	S_2 - 26th MW	157	428	578	851	1041	1422	1763	149	377	505	774	955	1286	1690
	S_3 - 27th MW	140	390	527	801	990	1357	1751	143	351	473	734	902	1256	1647
	S_4 - 28th MW	141	352	473	741	905	1278	1675	131	334	455	710	866	1220	1622
TAG-24	**S_1 - 25th MW**	112	344	464	725	868	1236	1562	107	381	511	762	935	1256	1557
	S_2 - 26th MW	157	396	532	788	974	1319	1624	149	349	461	718	885	1210	1523
	S_3 - 27th MW	124	361	481	740	915	1280	1585	128	323	441	691	831	1162	1494
	S_4 - 28th MW	112	322	410	667	828	1193	1547	104	303	396	641	795	1132	1489
JL-776	**S_1 - 25th MW**	146	389	508	779	971	1339	1739	137	425	566	837	1019	1359	1758
	S_2 - 26th MW	157	443	592	866	1057	1439	1826	149	392	521	788	969	1302	1723
	S_3 - 27th MW	140	405	542	817	1004	1370	1784	143	365	487	748	930	1274	1679
	S_4 - 28th MW	155	366	489	756	938	1312	1702	145	349	470	724	893	1253	1653

P_1: Sowing to germination, P_2: Germination to branching, P_3: Branching to first flower, P_4: First flower to 50 % flowering, P_5: 50 % flowering to peg formation, P_6: Peg formation to rapid kernel growth and P_7: Rapid kernel growth to physiological maturity

Table 2. Heat use efficiency as influenced by different sowing windows and varieties in *kharif* groundnut during 2017 and 2018

Treatment		Heat Use Efficiency (HUE) (g/GDD)											
		2017						2018					
Varieties	Sowing window	P_1	P_2	P_3	P_4	P_5	P_6	P_1	P_2	P_3	P_4	P_5	P_6
Jl-501	S_1 - 25th MW	0.022	0.038	0.036	0.044	0.068	0.059	0.019	0.037	0.037	0.044	0.070	0.062
	S_2 - 26th MW	0.020	0.036	0.034	0.041	0.068	0.060	0.023	0.046	0.042	0.050	0.078	0.069
	S_3 - 27th MW	0.018	0.032	0.032	0.039	0.063	0.054	0.022	0.042	0.040	0.048	0.073	0.062
	S_4 - 28th MW	0.018	0.032	0.034	0.040	0.063	0.053	0.019	0.038	0.040	0.046	0.071	0.059
RHRG-6083	S_1 - 25th MW	0.020	0.038	0.037	0.043	0.069	0.059	0.019	0.038	0.038	0.044	0.071	0.063
	S_2 - 26th MW	0.021	0.038	0.034	0.041	0.067	0.059	0.024	0.048	0.042	0.049	0.077	0.066
	S_3 - 27th MW	0.019	0.032	0.033	0.038	0.065	0.054	0.022	0.040	0.040	0.046	0.074	0.061
	S_4 - 28th MW	0.018	0.030	0.034	0.039	0.063	0.053	0.020	0.036	0.040	0.045	0.070	0.059
TAG-24	S_1 - 25th MW	0.020	0.035	0.034	0.043	0.065	0.058	0.019	0.036	0.036	0.044	0.068	0.063
	S_2 - 26th MW	0.021	0.035	0.032	0.040	0.064	0.060	0.024	0.045	0.039	0.049	0.074	0.068
	S_3 - 27th MW	0.018	0.031	0.031	0.038	0.060	0.053	0.020	0.039	0.037	0.046	0.070	0.061
	S_4 - 28th MW	0.019	0.032	0.032	0.039	0.064	0.051	0.020	0.039	0.038	0.046	0.072	0.057
JL-776	S_1 - 25th MW	0.021	0.039	0.036	0.044	0.073	0.061	0.019	0.039	0.037	0.046	0.075	0.064
	S_2 - 26th MW	0.026	0.047	0.041	0.044	0.088	0.075	0.030	0.057	0.049	0.052	0.100	0.083
	S_3 - 27th MW	0.019	0.033	0.032	0.040	0.069	0.056	0.022	0.042	0.039	0.047	0.078	0.064
	S_4 - 28th MW	0.017	0.033	0.028	0.032	0.065	0.056	0.017	0.042	0.037	0.040	0.074	0.058

P_1: Germination to branching, P_2: Branching to first flower, P_3: First flower to 50 % flowering, P_4 : 50 % flowering to peg formation, P_5: Peg formation to rapid kernel growth, P_6: Rapid kernel growth to physiological maturity

Table 3. Cumulative heliothermal unit (HTU) as influenced by different sowing windows and varieties in *kharif* groundnut during 2017 and 2018

Treatment		Cumulative heliothermal unit													
		2017							2018						
Varieties	**Sowing window**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**
Jl-501	**S_1 - 25th MW**	682	966	1318	2405	3140	5153	6875	60	217	580	965	1544	3968	6362
	S_2 - 26th MW	1241	2416	2619	3412	4191	5832	7818	525	1227	1348	1924	2176	3569	5988
	S_3 - 27th MW	624	1238	1562	2657	3170	4971	6961	299	425	643	1212	1422	3667	5973
	S_4 - 28th MW	355	1421	1646	2574	3254	4894	6909	645	769	868	1574	1739	3556	5746
RHRG-6083	**S_1 - 25th MW**	699	1109	1597	2648	3448	5340	7528	60	353	727	1126	1789	4221	7074
	S_2 - 26th MW	1241	2539	2685	3674	4306	6257	8171	525	1227	1354	2009	2183	4167	6230
	S_3 - 27th MW	624	1300	1621	2744	3434	5361	7438	299	430	765	1248	1719	3985	6740
	S_4 - 28th MW	355	1424	1682	2830	3439	5240	7334	645	785	868	1621	1839	4035	6639
TAG-24	**S_1 - 25th MW**	664	966	1237	2291	2981	4756	6612	60	217	567	958	1429	3552	6069
	S_2 - 26th MW	1241	2355	2615	3319	4166	5481	6974	525	1227	1348	1879	2145	3333	5333
	S_3 - 27th MW	453	1238	1562	2657	3161	4539	6400	290	425	643	1212	1420	3177	5111
	S_4 - 28th MW	296	1421	1568	2521	3127	5043	6639	599	767	847	1564	1672	3560	5477
JL-776	**S_1 - 25th MW**	699	1133	1695	2708	3707	5544	7805	62	407	749	1130	1964	4417	7365
	S_2 - 26th MW	1241	2551	2698	3699	4432	6315	8254	525	1230	1355	2075	2251	4230	6751
	S_3 - 27th MW	771	1377	1660	2744	3593	5489	7716	299	451	786	1248	1834	4126	6924
	S_4 - 28th MW	355	1436	1688	2868	3439	5240	7463	645	837	924	1629	1839	4084	6930

P_1: Sowing to germination, P_2: Germination to branching, P_3: Branching to first flower, P_4: First flower to 50 % flowering, P_5: 50 % flowering to peg formation, P_6: Peg formation to rapid kernel growth and P_7: Rapid kernel growth to physiological maturity

Table 4. Heliothermal use efficiency (g/HTU) as influenced by different sowing windows and varieties in *kharif* groundnut during 2017 and 2018

Treatment		Heliothermal use efficiency (g/HTU)											
		2017						2018					
Varieties	Sowing window	P_1	P_2	P_3	P_4	P_5	P_6	P_1	P_2	P_3	P_4	P_5	P_6
Jl-501	S_1 - 25th MW	0.0076	0.0128	0.0106	0.0124	0.0164	0.0138	0.0346	0.0330	0.0297	0.0277	0.0225	0.0159
	S_2 - 26th MW	0.0034	0.0075	0.0080	0.0098	0.0155	0.0132	0.0069	0.0163	0.0158	0.0205	0.0267	0.0184
	S_3 - 27th MW	0.0054	0.0101	0.0090	0.0115	0.0164	0.0128	0.0161	0.0279	0.0223	0.0283	0.0235	0.0160
	S_4 - 28th MW	0.0040	0.0082	0.0092	0.0106	0.0161	0.0121	0.0075	0.0181	0.0171	0.0220	0.0235	0.0157
RHRG-6083	S_1 - 25th MW	0.0069	0.0119	0.0106	0.0118	0.0171	0.0133	0.0220	0.0292	0.0278	0.0248	0.0228	0.0151
	S_2 - 26th MW	0.0036	0.0081	0.0080	0.0099	0.0152	0.0128	0.0075	0.0178	0.0161	0.0213	0.0239	0.0178
	S_3 - 27th MW	0.0057	0.0103	0.0095	0.0110	0.0165	0.0127	0.0176	0.0248	0.0233	0.0242	0.0234	0.0150
	S_4 - 28th MW	0.0045	0.0084	0.0088	0.0101	0.0155	0.0121	0.0085	0.0188	0.0173	0.0210	0.0212	0.0144
TAG-24	S_1 - 25th MW	0.0072	0.0131	0.0107	0.0126	0.0169	0.0138	0.0330	0.0326	0.0288	0.0288	0.0239	0.0161
	S_2 - 26th MW	0.0035	0.0071	0.0075	0.0095	0.0155	0.0139	0.0068	0.0154	0.0150	0.0201	0.0268	0.0194
	S_3 - 27th MW	0.0051	0.0097	0.0085	0.0110	0.0170	0.0132	0.0152	0.0271	0.0212	0.0272	0.0257	0.0178
	S_4 - 28th MW	0.0043	0.0083	0.0086	0.0105	0.0152	0.0119	0.0081	0.0181	0.0158	0.0218	0.0229	0.0156
JL-776	S_1 - 25th MW	0.0071	0.0115	0.0104	0.0115	0.0177	0.0135	0.0203	0.0291	0.0278	0.0236	0.0232	0.0152
	S_2 - 26th MW	0.0046	0.0103	0.0095	0.0105	0.0200	0.0166	0.0096	0.0221	0.0184	0.0223	0.0309	0.0212
	S_3 - 27th MW	0.0057	0.0109	0.0094	0.0112	0.0172	0.0130	0.0177	0.0259	0.0232	0.0240	0.0240	0.0154
	S_4 - 28th MW	0.0043	0.0097	0.0075	0.0087	0.0162	0.0127	0.0071	0.0213	0.0164	0.0195	0.0229	0.0138

P_1: Germination to branching, P_2: Branching to first flower, P_3: First flower to 50 % flowering, P_4 : 50 % flowering to peg formation, P_5: Peg formation to rapid kernel growth, P_6: Rapid kernel growth to physiological maturity

Table 5. Photothermal unit as influenced by different sowing windows and varieties in *kharif* groundnut during 2017 and 2018

Treatment		Photothermal unit													
		2017							2018						
Varieties	Sowing window	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Jl-501	S_1 - 25th MW	2062	3333	1761	3250	2474	4092	4463	1957	3226	1691	3183	2326	3763	4426
	S_2 - 26th MW	1830	3271	1762	3431	2332	4471	4586	1879	3052	1645	3369	2241	4021	4717
	S_3 - 27th MW	1690	2603	1513	3251	2116	4446	4038	1595	2453	1493	3120	2065	4048	4122
	S_4 - 28th MW	1653	2515	1305	3342	2021	4667	3856	1545	2379	1343	3197	1915	4374	3883
RHRG-6083	S_1 - 25th MW	2062	3333	1761	3250	2474	4092	4463	1957	3420	1852	3390	2263	4157	4069
	S_2 - 26th MW	1830	3271	1762	3431	2332	4471	4586	1879	3052	1645	3369	2241	4021	4717
	S_3 - 27th MW	1690	3182	1502	3428	2112	4631	4429	1595	2978	1530	3258	2066	4290	4491
	S_4 - 28th MW	1840	2705	1523	3319	2011	4499	4542	1716	2595	1518	3162	1917	4254	4601
TAG-24	S_1 - 25th MW	2062	3130	1766	3251	2319	4230	3674	1957	3038	1696	3185	2151	3944	3609
	S_2 - 26th MW	1623	3099	1571	3240	2164	4469	3615	1673	2895	1458	3217	2073	3970	3719
	S_3 - 27th MW	1469	3024	1513	3251	1772	4477	3814	1406	2811	1493	3120	1728	4022	3886
	S_4 - 28th MW	1461	2706	1107	3197	1986	4434	4098	1359	2565	1163	3049	1897	4094	4131
JL-776	S_1 - 25th MW	2062	3743	1944	3439	2362	4665	4543	1957	3615	1836	3401	2250	4164	4677
	S_2 - 26th MW	1830	3474	1746	3440	2308	4450	4818	1879	3246	1651	3346	2230	4051	4891
	S_3 - 27th MW	1907	3156	1500	3367	2362	4453	4591	1795	2960	1535	3242	2242	4154	4652
	S_4 - 28th MW	2024	2701	1541	3305	2234	4478	4466	1890	2616	1509	3148	2068	4324	4568

P_1: Sowing to germination, P_2: Germination to branching, P_3: Branching to first flower, P_4: First flower to 50 % flowering, P_5: 50 % flowering to peg formation, P_6: Peg formation to rapid kernel growth and P_7: Rapid kernel growth to physiological maturity

Table 6. Photothermal use efficiency (g/PTU) as influenced by different sowing windows and varieties in *kharif* groundnut during 2017 and 2018

Treatment		2017						2018					
Varieties	**Sowing window**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**
Jl-501	**S_1 - 25th MW**	0.0022	0.0096	0.0079	0.0158	0.0207	0.0212	0.0023	0.0113	0.0090	0.0184	0.0237	0.0228
	S_2 - 26th MW	0.0025	0.0112	0.0080	0.0175	0.0203	0.0226	0.0028	0.0134	0.0090	0.0199	0.0237	0.0233
	S_3 - 27th MW	0.0026	0.0104	0.0074	0.0173	0.0184	0.0220	0.0028	0.0120	0.0087	0.0195	0.0213	0.0232
	S_4 - 28th MW	0.0023	0.0103	0.0071	0.0171	0.0169	0.0216	0.0024	0.0117	0.0084	0.0200	0.0191	0.0232
RHRG-6083	**S_1 - 25th MW**	0.0023	0.0108	0.0087	0.0164	0.0224	0.0224	0.0023	0.0114	0.0092	0.0196	0.0231	0.0262
	S_2 - 26th MW	0.0028	0.0124	0.0085	0.0183	0.0213	0.0228	0.0030	0.0147	0.0096	0.0207	0.0248	0.0236
	S_3 - 27th MW	0.0023	0.0111	0.0076	0.0179	0.0191	0.0213	0.0025	0.0124	0.0089	0.0201	0.0217	0.0225
	S_4 - 28th MW	0.0024	0.0092	0.0075	0.0173	0.0180	0.0196	0.0026	0.0108	0.0089	0.0201	0.0201	0.0208
TAG-24	**S_1 - 25th MW**	0.0022	0.0092	0.0075	0.0161	0.0190	0.0248	0.0024	0.0109	0.0087	0.0191	0.0216	0.0271
	S_2 - 26th MW	0.0026	0.0118	0.0077	0.0182	0.0190	0.0268	0.0029	0.0143	0.0087	0.0208	0.0225	0.0278
	S_3 - 27th MW	0.0021	0.0100	0.0070	0.0197	0.0172	0.0222	0.0023	0.0117	0.0082	0.0224	0.0203	0.0234
	S_4 - 28th MW	0.0022	0.0118	0.0067	0.0165	0.0173	0.0193	0.0024	0.0132	0.0081	0.0192	0.0199	0.0207
JL-776	**S_1 - 25th MW**	0.0022	0.0101	0.0082	0.0181	0.0210	0.0233	0.0023	0.0119	0.0092	0.0206	0.0246	0.0240
	S_2 - 26th MW	0.0034	0.0158	0.0102	0.0201	0.0283	0.0284	0.0037	0.0181	0.0114	0.0225	0.0322	0.0293
	S_3 - 27th MW	0.0025	0.0121	0.0077	0.0170	0.0212	0.0218	0.0027	0.0133	0.0089	0.0196	0.0238	0.0229
	S_4 - 28th MW	0.0023	0.0106	0.0065	0.0134	0.0189	0.0212	0.0023	0.0130	0.0085	0.0174	0.0216	0.0210

P_1: Germination to branching, P_2: Branching to first flower, P_3: First flower to 50 % flowering, P_4 : 50 % flowering to peg formation, P_5: Peg formation to rapid kernel growth, P_6: Rapid kernel growth to physiological maturity

4. CONCLUSIONS

Higher GDD was observed in 26th MW sowing window in variety JL-776 (1826 and 1723) and RHRG-6083 (1763 and 1690) this was followed var. JL-501 and TAG-24 during 2017 and 2018, respectively. Higher heat use efficiency (0.088 and 0.100 g/GDD) at Peg formation to rapid kernel growth stage was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) during 2017 and 2018, respectively. The highest HTU observed in 26th MW sowing window in variety JL-776 (8254 and 6924) and RHRG-6083 (8171 and 7074) this was followed var. JL-501 and TAG-24 during 2017 and 2018, respectively. Higher heliothermal use efficiency (0.0200 and 0.0309 g/HTU) at Peg formation to rapid kernel growth stage was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) during 2017 and 2018, respectively. Photothermal unit (PTU) for different genotypes varied considerably at different phenophase of crop. Higher PTU (4818 and 4890) was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) this was followed by var. RHRG-6083, JL-501 and TAG-24 during 2017 and 2018, respectively. Higher photothermal use efficiency (0.0284 and 0.293 g/PTU) at physiological maturity was observed under 26th MW sowing window (S_2) in variety JL-776 (V_2) this was followed by var. RHRG-6083, JL-501 and TAG-24 during 2017 and 2018, respectively.

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