Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(4): 1060-1066
Received: 17-05-2020
Accepted: 19-06-2020

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Impact of heat stress on physiological and yield components under varied temperature regimes in groundnut cultivars

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Abstract
Heat stress is one of the major abiotic stress plants experiencing now a day due to the changing climate. There may be a natural or manmade reason behind this but its impact on living organisms is vicious. The primarily important sector, Agriculture is the highly affected sector among all. Especially the noticeable reduction in quantity as well as quality of production was reported in different crop species. Groundnut is one of the most popular oilseed crop grown in India which faces various temperature regimes and heat stress during its life cycle. Therefore to know the impact of heat stress on physiological and yield components under various temperature regimes in groundnut a field experiment was conducted at MARS, University of Agricultural Sciences, Dharwad during 2016-17. The experiment consisted of three dates of sowing (D_1, D_2, and D_3) and five groundnut genotypes (Dh-86, G-2-52, Kadiri-9, TMV-2 and R-2001-2) laid out with factorial RBD design. Among the dates of sowing, almost all the genotypes performed better under D_1 temperature regime than D_2 and D_3 temperature regimes. All the yield components like; test weight, harvest index, oil and protein content recorded significantly higher value under D_1 temperature regime whereas among the genotypes Dh-86 and G-2-52 recorded significantly higher values regarding yield components, thus considered as tolerant varieties.

Keywords: Heat stress, temperature regime, tolerant genotype, harvest index, yield

Introduction
Groundnut (*Arachishypogaea* L.) is the fore most important oil seed crop of India which, depends mainly on temperature for its growth and development. With the present trends of global warming due to climate change, increasing temperature is likely to cause change in the geographical distribution and growing season of the crop by causing the threshold temperatures to reach early maturity depending upon its intensity, duration and stages of exposure to heat stress. Although hot and warm climate are suitable for groundnut cultivation, extreame temperature and water deficit plays a key role in decreased production (ICRISAT 1994). Therefore the Improvement of resistant varieties is the primary concern for the long-term viability and maintenance peanut production. Yield was significantly affected by short chapter of high temperature stress exposer in groundnut (Vara Prasad *et al*. 2001). High temperatures (> 35°C) slow down plant growth and as groundnut plants are very sensitive to low temperatures, seeds should only be planted when the minimum temperature stabilises above 18 °C. Global temperature is increasing possibly due to climate change, which would have detrimental effects on agricultural crops being grown in arid and semi–arid regions. Plants are having two options, either enhance their inherent ability or ability to acquire tolerance to survive well in high temperature stress. (Rampino *et al*. 2009) [23]. Growing plants in their natural habitat with a normal temperature range when experience high temperatures, in absence of acclimation may cause severe damage to plant and hence improvement of thermotolerance acquiring ability is of significant importance to the plants (Senthil-Kumar *et al*. 2007) [24].

High-temperature stress in plants can be overcome by a number of physiological and biochemical mechanisms (Rampino *et al*. 2009) [23] In addition, increasing temperature is likely to cause change in the geographical distribution and growing season of the crop by causing the threshold temperatures to reach early maturity depending upon its intensity, duration and stages of exposure to heat stress can adversely affect the rate of growth and development of plants. Generally chlorophyll and carotenoid content varies with fluctuation in temperature and plays a vital role in photosynthesis and photo-oxidation, respectively, which results in variation in yield of groundnut.

Material and Methods

The field experiment was conducted in *kharif*, 2016-17 at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad situated at $15^0$12' N latitude and $76^0$34'E longitude with an altitude of 678 m above mean sea level.

Plant material and growth conditions

The experimental site consisted of medium deep black soil and the crop was raised in a plot size of 3.5 × 2.5 m with a spacing of 30 × 10 cm, fertilized with 25:50:25 kg of N: P_2O_5: K_2O. The temperature regimes were created through three dates of sowing ie., D_1 (24^{th} MSW -15^{th} June), D_2 (28^{th} MSW -15^{th} July), D_3 (33^{rd} MSW -15^{th} August) with five Genotypes **(**Dh-86, G-2-52, Kadiri-9, TMV-2 and R-2001-2). The experiment was done by using a factorial randomized block design (FRBD) with three replications. The genotypes (Dh-86, G-2-52, Kadari-9, TMV-2 and R-2001-2) in combination with three different dates of sowing were considered for the present experiment. (Figure 2)

Temperature variation in three temperature regimes

The highest mean maximum temperature (31.54^0C) was recorded under 44^{th} SMW (29^{th} October to 4^{th} November) followed by (31.13^0C) 43^{rd} SMW (22^{nd} October-28^{th} October) and the minimum temperature ranges from 12.56^0C to 21.53^0C. Under 28^{th} SMW (9^{th} July -15^{th} July) received highest rainfall (7.6 mm) followed by (6.29 mm) 39^{th} SMW (24^{th} September -30^{th} September).(Figure-1)

Chlorophyll and carotenoid evalution under different temperature regimes

The chlorophyll and carotenoid content was measured by taking fresh leaf tissue (50 mg) and was cut into small pieces and incubated in 10 ml of Dimethyl Sulfoxide (DMSO) in dark for 24 hr. Later, the optical density was measured at 645 and 663 and 480 nm in UV-VIS Spectrophotometer. Care was taken to make the final volume to 10 ml. Chlorophyll-a, chlorophyll-b, chlorophyll a/b ratio, total chlorophyll and carotenoid contents were calculated by following the methodology given by Shoaf and Lixm, 1976 [25].

Estimation of Membrane injury index (MII %)

The membrane injury index (%) was measured according to the procedure of Sullivan test (1972) [29] at an interval of 15 days, starting from the day of 50 per cent flowering. Five leaf discs of the test samples were taken in a test tube with 10 ml of distilled water. The covered test tubes were kept for one hour at room temperature. Then the test tubes were exposed to two high temperatures i.e. 45 ºC for 30 minutes and 100 ºC for 10 minutes in water bath and autoclave respectively. The respective EC were recorded at room temperature (EC_a), after exposer to 45^0C ((EC_b) and 100^0C (EC_c). Membrane injury index was calculated by using the following formula.

$$\text{Membrane injury index (\%)} \quad \frac{EC_b - EC_a}{EC_c} \times 100$$

Measurement of Photosynthetic rate, transpiration rate and stomatal conductivity

The index leaf (third leaf from top) was selected to measure net photosynthetic rate (Ps), transpiration rate (Tr) and stomatal conductance (g_s) by using IRGA (Infrared gas analyzer) of LI-6400XT Portable Photosynthesis System at 50 % flowering stage.

Yield and yield components

Yield and yield component were measured at physiological maturity and Pod yield $kgha^{-1}$, Seed Test weight (g), Shelling per cent (%), Harvesting index (%), Oil (%), Protein (mg g^{-1}) were recorded for further analysis. The weight of hundred seeds was recorded from the seed samples obtained from each treatment and expressed in grams for test weight calculation. Pod and seed dry weight of 5 tagged plants are taken at harvest and shelling percentage was calculated by using the following formula and expressed in percentage. Further harvest index, a ratio of economic yield to total biological yield was estimated using formula given by Donald, 1962 [8] and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (g plant}^{-1})}{\text{Total biological yield (g plant}^{-1})} \times 100$$

Oil estimation and percentage of oil in groundnut oven dried kernel was recorded, at AICRP groundnut, MARS UAS Dharwad. Protein content was calculated by multiplying the constant factor 6.25 with nitrogen percentage which was estimated by Kjedahl digestion and distillation method (Taudon, 1998) [31].

Result and Discussion

Photosynthetic pigments (chlorophyll and carotenoids) and their ratio are good indicators for stress detection and tolerance. High chlorophyll a/b ratio was associated with adoptability with low and high temperature. High temperature stress induced a decrease in chlorophyll content, greater damage to thylakoid membranes and an increase in *Chl*a/b ratio in leaf discsin heat susceptible cultivars than heat tolerant cultivars (Chen Lisong *et al.*, 1997 and Zoran Ristic *et al.*, 2008) [5, 34]. Early growth stages are found with low Chlorophyll content in t due to the limited soil nutrient uptake, especially (N) for pigment synthesis (Pandey *et al.*, 2001) [19]. In present investigation a decrease in chlorophyll a, b and total chlorophyll content was noticed from planting to maturity. Prasad *et al*. (2011) [20] reported that high night temperature decreased chlorophyll content compared to optimum night temperature. Similarly in present investigation later period of maturity (41^{st} to 47^{th} SMW) a drastic decrease in temperature in the range of 12 to 17 ^{0}C played a major role in chlorophyll content of the leaf. Among the dates of sowing, D1 temperature regime recorded significantly higher chl a content, while, chl b and total chlorophyll content was higher at D2 temperature regime. However, *Chl*a/b ratio was shown higher value during 50 % flowering under D1 temperature regime. This may be due to prevalence of ideal range between higher and lower temperature during D1 temperature regime (Figure 1) than D_2 temperature regime. Chlorophyll a did not alter significantly, whereas, chlorophyll b pigment increased with delayed sowing and hence chlorophyll a/b ratio decreased. In general it is established that under stressed condition (high or low temperatures) the chlorophyll-b will be more. The genotype, G-2-52 maintained higher chlorophyll (2.330 mg g^{-1} of fresh weight) content and R-2001-2 (1.158 mg g^{-1} of fresh weight) recorded significantly lower chlorophyll content. (Table-1)

It is established that carotenoids prevent photo oxidation of chlorophyll under adverse conditions. Maintenance of high

carotenoid content in leaf prevents photo oxidation of chlorophyll pigment. In general, the carotenoid content increased there by inhibiting the photo oxidation process as evidenced from the present study also that total chlorophyll content increased from D_1 to D_3 temperature regime. Among the genotypes, Dh-86, G-2-52, Kadiri-9 maintained higher carotenoid content at 50 % flowering which resulted in maintenance of higher chlorophyll content because of higher carotenoid content by these genotypes at the same stages. Similar results were also optained by Asha (2016) [1]. (Table-1)

A negative influence of high temperature can affect the physiological fitness of peanut plants. High temperature stress induced an increase in the leakage of electrolytes (Chen and Liu, 1997; Nautiyal *et al*., 2005; Singh *et al*., 2016 and Asha, 2016) [6, 18, 26, 1]. Cell membrane is the site that gets affected first for both heat and cold injury, and hence more leakage of cellular constituents was observed (Sung *et al*., 2003; Larkindale *et al*., 2004; Xu *et al*., 2006; Kumar *et al*., 2012 and Mukesh, 2015) [30, 15, 32, 14, 17]. The present study on Membrane Injury Index (MII) did not indicate a clear trend for different temperature regimes but D_1 temperature regime showing a lower MII (70.28%) than both D_2(84.00%)and D_3(78.16%) temperature regimes. In general irrespective of dates of sowing the MII increased numerically with delayed sowing. From present study it is evident that MII was not much influenced by dates of sowing with respect to genetic variation. (Table-2)

Photosynthesis and transpiration rate can be measured on the basis of stomatal density, size and degree of opening; greater conductance due to more open stomata leads to potentially higher photosynthesis and transpiration rates. During reproductive development when temperate species are manifest to heat stress a rapid reduction in Photosynthetic capacity was observed (Harding *et al*., 1990) [9]. During heat treatment, the stomatal conductance (Gs), net photosynthetic rate (Pn), and transpiration rates (Tr) of both heat-acclimated (HA) and non-acclimated (NA) plants were drastically decreased (Zhao *et al*., 2014) [33]. Similarly, in the present investigation photosynthetic rate, stomatal conductance and transpiration rate recoded significantly higher value at D_1 temperature regime compared to delayed sowings (D_2 and D_3 temperature regime). Under D_1 temperature regime the minimum temperature prevailed was 12.1 ^{0}C while under D_2 (19.8 ^{0}C) and D_3 (18 ^{0}C). Genetic variations were observed for photosynthetic rate, stomatal conductance and transpiration rate, among genotypes, Dh-86 recoded significantly higher value for photosynthetic rate (26.83), stomatal conductance (0.403) and transpiration rate (7.226) at 50 % flowering. The genotype Dh-86 recorded higher canopy temperature and chlorophyll content resulted in higher photosynthetic rate. (Table-2)

Temperature is the primary factor affecting plant growth and development which is ultimately affects the plant yield by controlling morphological, phenoogical and physiological growth parameters. Peanut was significantly affected by sowing time as under ecological conditions and early sowing time at the mid-April led to increases in pod yield compared to late sowing time of peanut crops (Sogut *et al*., 2016) [27]. Under delayed / late planting growth period was shortened for both vegetative and generative duration thus, number of pods per plant, shelling per cent and 100 seed weight of groundnut cultivar were lower (Banterng *et al.*, 2003; Karanjikar *et al.*, 2004 and Caliskan *et al.*, 2008) [2, 10, 3]. Dates of sowing, affects the number of pegs and pod set in groundnut. As temperature increases due to delayed sowing number of pegs in groundnut cultivars were also increased, but there was adverse effect on pod set (Ketring, 1984; Kiran and Chimmad 2017 and Prasad *et al*., 2003) [11, 12, 21].

In present investigation similar results were obtained. Where, early sowing date (D1 temperature regime) recorded significantly higher pod yield ha^{-1} (4952 kg ha^{-1}) which was decreased as the sowing delay. There was no significant differences observed among genotypes. However, among interactions, Dh-86 (6325 kg ha^{-1}) recorded significantly higher pod yield followed by G-2-52 under D_1 temperature regimes. (Table-3)

Three tested genotypes (ICG 1236, ICGS 44 and Chico) were shown a significantly reduced seed setting rate and seed weight under an apex temperature of 35/30 ºC compared to 25/25 ºC. Shelling percentage was 60-76 per cent at 25/25 ºC and 41-62 % at 35/30 ºC for three genotypes. Prasad *et al.* (2003) [21] reported that shelling per cent decreases from 82 to 74 percent (0.7 units/ºC) as temperature increases from 32/22 to 44/34 ºC. Thus, high temperature decreases the shelling percent. Similar results were obtained from current study, where shelling per cent was lower under D1 temperature regime (47.56 %) due to higher T_{max} followed by D_2 and D_3 temperature regime. Among genotype G-2-52 (66.28 %) recorded significantly higher shelling percentage followed by kadiri-9 and Dh-86.Whereas, among interactions, G-2-52 under D_3 temperature regime recorded significantly higher shelling percentage. (Table-3)

Pod HI of the groundnut genotypes increased linearly with time until maturity irrespective of the growing temperature but the higher temperatures (30 ºC) caused slower HI increasing rate and the lower HI values at final harvest (Craufurd *et al*., 2002). Harvest index was reduced by more than 59 per cent at higher temperature 35/30 ºC (Chaitra *et al*. 2018; Kiran and Chimmad, 2018, Craufurd *et al*., 2002; Prasad *et al*., 2003 and Meena *et al*., 2015) [13, 21, 16]. Similar results were obtained in present study also, where highest test weight (g) and harvest index (%) was recorded under D1 temperature regime (35.78 g and 31.78 % respectively) and reduced linearly with delayed sowing. Among genotypes Kadiri-9 and G-2-52 recorded higher test weight and harvest index respectively. (Table-3)

Sogut *et al*. (2016) [28] reported that Contrary to oil content, higher protein content was recorded for plants obtained from late sowing times. Present investigation is supported by the above research article as here the Oil content and Protein content showed an inverse relation. Where, D1 and D_3 temperature regimes showed higher oil content and significantly lower oil content was recorded in D2 temperature regime. However, D2 temperature regimes recorded significantly higher protein content. Among genotypes G-2-52 and Dh-86 recorded significantly higher oil and protein content. Among interactions Kadiri-9 and Dh-86 recorded significantly higher oil and protein content under D_3 temperature regime respectively (Table-3).

In conclusion D_1 temperature regimes showed an over ally good performance with respect to heat unit accumulation, canopy temperature, chlorophyll content, photosynthetic rate, stomatal conductance, transpiration rate, pollen sterility, dry matter accumulation and yield. Whereas, among genotypes, Dh-86 and G-2-52 performed better regarding canopy temperature, maintained chlorophyll content, carotenoid content, flower to pod ratio and yield. Whereas, under stressed condition (D2 and D3 temperature regimes) genotype, R-2001-2 recorded higher flower count and a maintained pollen sterility which showed its better

adoptability in stressed condition. Further, among genotypes a significant difference was seen regarding total flower number but daily production rate fluctuated differentially among the genotypes. Similarly the continuation of the flowering period differs under different temperature regimes, which indicates the differential response of flowering duration by genotypes under different temperature regimes. Interestingly, the daily observations on pollen sterility indicated that the fluctuation in temperature (T_{max} and T_{min}) will not be same for the different genotypes i.e. a genotype showing higher sterility under higher temperature may not have similar response from other genotypes. The genotypes recorded fluctuating responses (sterility peaks) for varied T_{max} and T_{min}.

Table 1: Effect of temperature regimes on chlorophyll and Carotenoid content at 50% flowering stages in groundnut genotypes

	Chlorophyll –a (mg g^{-1} fresh weight)	Chlorophyll-b (mg g^{-1} of fresh weight)	Total chlorophyll (mg g^{-1} fresh weight)	Chlorophyll a/b	Carotenoid content (mg g^{-1} fresh weight)
Dates of sowing (D)					
12-06-2016 (D_1)	1.289	0.288^{b}	1.578^{b}	5.274^{a}	2.311^{b}
13-07-2016 (D_2)	1.264	0.671^{a}	1.935^{a}	1.883^{b}	2.668^{ab}
13-08-2016 (D_3)	1.313	0.652^{a}	1.964^{a}	2.000^{b}	2.788^{a}
S. Em. ±	0.050	0.034	0.079	0.194	0.128
LSD @ 5 %	NS	0.098	0.228	0.561	0.370
Genotypes (G)					
Dh-86 (G_1)	1.334^{ab}	0.616^{a}	1.950^{ab}	2.565	2.699^{ab}
$G^{-}2$-52 (G_2)	1.481^{a}	0.606^{a}	2.087^{a}	3.015	2.955^{a}
Kadiri-9 (G_3)	1.321^{ab}	0.537^{ab}	1.857^{a-c}	3.292	2.712^{ab}
$TMV^{-}2$ (G_4)	1.203^{bc}	0.469^{b}	1.672^{bc}	3.094	2.376^{b}
$R^{-}2001$-2 (G_5)	1.105^{c}	0.458^{b}	1.562^{c}	3.295	2.202^{b}
S. Em. ±	0.064	0.044	0.101	0.250	0.165
LSD @ 5 %	0.186	0.127	0.294	NS	0.473
Interaction (D×G)					
D_1G_1	1.203^{b-d}	0.450^{cd}	1.652^{b-e}	3.713^{b}	2.180^{c-e}
D_1G_2	1.539^{ab}	0.349^{de}	1.888^{a-d}	5.096^{a}	2.547^{a-e}
D_1G_3	1.223^{a-d}	0.210^{e}	1.432^{de}	5.960^{a}	2.645^{a-e}
D_1G_4	1.492^{a-c}	0.267^{e}	1.759^{a-d}	5.574^{a}	2.490^{b-e}
D_1G_5	0.991^{d}	0.167^{e}	**1.158^{e}**	6.030^{a}	1.694^{e}
D_2G_1	1.222^{a-d}	0.645^{ab}	1.867^{a-d}	1.894^{c}	2.456^{b-e}
D_2G_2	1.458^{a-c}	0.755^{a}	2.203^{ab}	1.956^{c}	3.134^{a-c}
D_2G_3	1.354^{a-d}	0.723^{a}	2.078^{a-c}	1.873^{c}	2.744^{a-d}
D_2G_4	1.117^{cd}	0.621^{a-c}	1.738^{a-d}	1.804^{c}	2.511^{a-e}
D_2G_5	1.168^{b-d}	0.620^{a-c}	1.788^{a-d}	1.886^{c}	2.496^{b-e}
D_3G_1	1.576^{a}	0.754^{a}	**2.330^{a}**	2.089^{c}	3.461^{a}
D_3G_2	1.447^{a-c}	0.723^{a}	2.170^{ab}	1.991^{c}	3.186^{ab}
D_3G_3	1.385^{a-c}	0.677^{ab}	2.062^{a-c}	2.044^{c}	2.748^{a-d}
D_3G_4	1.00^{d}	0.518^{b-d}	1.518^{c-e}	1.905^{c}	2.128^{de}
D_3G_5	1.155^{cd}	0.587^{a-c}	1.742^{a-d}	1.967^{c}	2.417^{b-e}
S. Em. ±	0.111	0.076	0.176	0.433	0.286
LSD @ 5 %	0.323	0.220	0.509	1.255	0.828

Note: D_1 (24th Standard Meteorological Week): 12-06-2016 date of sowing
D_2 (28th Standard Meteorological Week): 13-07-2016 date of sowing
D_3 (33rd Standard Meteorological Week): 13-08-2016 date of sowing
Alphabets in the column followed by the same letter do not differ significantly as per DMRT

Table 2: Effect of temperature regimes on different physiological parameters at 50% flowering stage of different groundnut genotypes.

	Membrane injury index (%)	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})	Stomatal conductance (mol H_2O m^{-2} s^{-1})	Transpiration Rate (mmol H_2O m^{-2} s^{-1})
Dates of sowing (D)				
12-06-2016 (D_1)	70.28^{b}	26.47^{a}	0.368^{a}	7.098^{a}
13-07-2016 (D_2)	84.00^{a}	23.94^{c}	0.357^{a}	6.872^{b}
13-08-2016 (D_3)	78.16^{ab}	24.25^{b}	0.324^{b}	6.575^{c}
S. Em. ±	3.38	0.73	0.006	0.055
LSD @ 5 %	9.79	0.29	0.016	0.159
Genotypes (G)				
Dh-86 (G_1)	76.25	26.83^{a}	0.403^{a}	7.226^{a}
$G^{-}2$-52 (G_2)	73.38	25.84^{ab}	0.366^{b}	7.116^{ab}
Kadiri-9 (G_3)	79.48	23.51^{b}	0.327^{cd}	6.597^{c}
$TMV^{-}2$ (G_4)	80.22	23.50^{b}	0.308^{d}	6.345^{d}
$R^{-}2001$-2 (G_5)	78.07	24.77^{ab}	0.343^{c}	6.959^{b}
S. Em. ±	4.36	0.95	0.007	0.071
LSD @ 5 %	NS	2.74	0.021	0.206
Interaction (DXG)				
D_1G_1	76.26	28.57^{a}	0.431^{a}	7.506^{a}
D_1G_2	71.76	27.87^{ab}	0.384^{bc}	7.365^{ab}

D_1G_3	73.34	25.43^{a-c}	0.337^{d-f}	6.855^{cd}
D_1G_4	65.15	24.93^{a-c}	0.320^{e-g}	6.582^{de}
D_1G_5	64.90	25.57^{a-c}	0.368^{b-d}	7.182^{a-c}
D_2G_1	80.57	25.89^{a-c}	0.405^{ab}	7.220^{a-c}
D_2G_2	83.97	24.65^{a-c}	0.378^{bc}	7.103^{bc}
D_2G_3	84.13	22.90^{bc}	0.335^{d-f}	6.630^{de}
D_2G_4	86.58	21.85^{c}	0.312^{fg}	6.331^{ef}
D_2G_5	84.77	24.42^{a-c}	0.354^{c-e}	7.075^{bc}
D_3G_1	71.91	26.03^{a-c}	0.373^{b-d}	6.951^{cd}
D_3G_2	64.39	25.00^{a-c}	0.336^{d-f}	6.879^{cd}
D_3G_3	80.98	22.19^{c}	0.309^{fg}	6.305^{ef}
D_3G_4	88.94	23.71^{a-c}	0.292^{g}	6.121^{f}
D_3G_5	84.55	24.31^{a-c}	0.308^{fg}	6.621^{de}
S. Em. ±	7.56	26.47	0.012	0.123
LSD @ 5 %	NS	4.75	0.036	0.356

Note: D_1 (24th Standard Meteorological Week): 12-06-2016 date of sowing
D_2 (28th Standard Meteorological Week): 13-07-2016 date of sowing
D_3 (33rd Standard Meteorological Week): 13-08-2016 date of sowing
Alphabets in the column followed by the same letter do not differ significantly as per DMRT

Table 3: Effect of temperature regimes on plant dry weight, test weight, harvesting index (%) and Pod yield of different groundnut genotypes at Harvest

	Seed Test weight (g)	**Shelling per cent (%)**	**Harvesting index (%)**	**Oil (%)**	**Protein (mg g^{-1})**	**Pod yield kgha^{-1}**
Dates of sowing (D)						
12-06-2016 (D_1)	35.78^{a}	47.56^{c}	31.78^{a}	44.26^{a}	27.68^{b}	4952^{a}
13-07-2016 (D_2)	30.37^{b}	57.20^{b}	27.65^{b}	41.07^{b}	28.46^{a}	2191^{b}
13-08-2016 (D_3)	32.30^{b}	67.23^{a}	28.07^{ab}	44.13^{a}	25.93^{c}	1164^{c}
S. Em. ±	0.98	2.79	1.31	0.11	0.05	1852
LSD @ 5 %	2.85	8.07	3.79	0.32	0.13	536
Genotypes (G)						
Dh-86 (G_1)	30.01^{b}	57.82^{ab}	30.34^{a}	42.00^{b}	31.74^{a}	3069
G^{-}2-52 (G_2)	33.49^{ab}	66.28^{a}	34.22^{a}	45.46^{a}	29.25^{b}	3074
Kadiri-9 (G_3)	35.20^{a}	59.38^{ab}	29.79^{a}	45.09^{a}	25.57^{d}	2398
TMV^{-}2 (G_4)	31.83^{ab}	54.19^{b}	20.52^{b}	41.39^{c}	24.28^{e}	2440
R^{-}2001-2 (G_5)	33.58^{ab}	48.97^{b}	30.97^{a}	41.83^{b}	25.93^{c}	2863
S. Em. ±	1.27	3.60	1.69	0.14	0.06	239
LSD @ 5 %	3.68	10.43	4.89	0.41	0.17	NS
Interaction (DXG)						
D_1G_1	32.19^{a-c}	51.96^{b-d}	37.36^{ab}	44.94^{b}	30.04^{c}	6325^{a}
D_1G_2	35.67^{ab}	48.32^{cd}	33.45^{a-d}	45.67^{b}	25.56^{h}	5239^{ab}
D_1G_3	37.00^{ab}	51.29^{b-d}	31.51^{a-d}	45.13^{b}	26.59^{f}	4388^{bc}
D_1G_4	37.73^{a}	46.23^{cd}	27.57^{b-e}	43.89^{c}	28.02^{e}	4345^{bc}
D_1G_5	36.33^{ab}	39.99^{d}	29.01^{b-d}	41.69^{e}	28.19^{e}	4464^{bc}
D_2G_1	27.33^{c}	59.77^{b-d}	28.80^{b-d}	37.97^{g}	31.78^{b}	1948de
D_2G_2	32.07^{a-c}	64.51^{bc}	40.05^{a}	45.27^{b}	31.90^{b}	2260de
D_2G_3	32.87^{a-c}	55.02^{b-d}	25.99^{c-e}	43.59^{cd}	23.82^{i}	1475^{e}
D_2G_4	29.93^{bc}	55.98^{b-d}	15.09^{f}	38.41^{g}	26.21^{g}	2076de
D_2G_5	29.67^{bc}	50.71^{b-d}	28.33^{b-d}	40.13^{f}	28.59^{d}	3197^{cd}
D_3G_1	30.50^{a-c}	61.72^{bc}	24.87^{de}	43.09^{d}	33.39^{a}	934^{e}
D_3G_2	32.73^{a-c}	86.01^{a}	29.17^{b-d}	45.44^{b}	30.30^{c}	1724^{e}
D_3G_3	35.73^{ab}	71.84^{ab}	31.86^{a-d}	46.56^{a}	26.29^{g}	1331^{e}
D_3G_4	27.82^{c}	60.37^{b-d}	18.91^{ef}	41.88^{e}	18.63^{k}	900^{e}
D_3G_5	34.73^{a-c}	56.22^{b-d}	35.56^{a-c}	43.67^{cd}	21.02^{j}	928^{e}
S. Em. ±	2.20	6.24	2.92	0.24	0.10	414
LSD @ 5 %	6.37	18.07	8.46	0.71	0.30	1200

Note: D_1 (24th Standard Meteorological Week): 12-06-2016 date of sowing
D_2 (28th Standard Meteorological Week): 13-07-2016 date of sowing
D_3 (33rd Standard Meteorological Week): 13-08-2016 date of sowing
Alphabets in the column followed by the same letter do not differ significantly as per DMRT

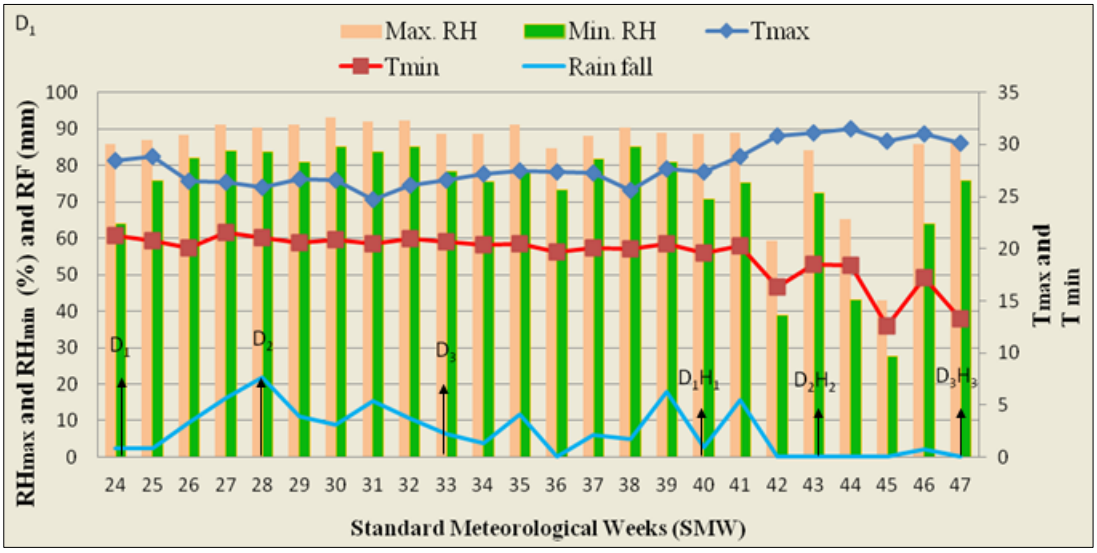

Fig 1: Weekly meteorological data at main agriculture research station (MARS), UAS, Dharwad

Fig 2: General view of experimental plot for different dates of sowing

Acknowledgement
I would like to thanks my adviser Dr. V. P. Chimmad for his proper guidance throughout my study. I am also great full to the Department of Crop Physiology, UASD for providing all the facilities needed for the research work.

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