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Impact of Heat Stress on Yield and Yield Components of Groundnut (*Arachis hypogaea* L.) Genotypes under Varied Dates of Sowing

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Abstract An investigation on impact of heat stress on yield and yield components of groundnut (*Arachis hypogaea* L.) genotypes with 4 different dates of sowing and 4 genotypes under factorial RBD was under taken in 2015 *(kharif)*. The obtained results revealed that 23rd standard week (D_1 temperature regime) recorded higher value in pod yield (3,504 kg ha^{-1}) and yield components viz., number of pods per plant (15.75), number of seeds per plant (27.25), pod weight (14.02g), seed weight (10.67 g), haulm weight (3.35g), shelling percent (76.21%), test weight (35.46g), harvest index (51.97%) were reduced gradually with delayed sowing (D_2, D_3 and D_4 temperature regimes, respectively). Among the 4 genotypes G2-52 and Dh-86 were found to be better performer at heat temperature.

Keywords Groundnut, Temperature regimes, Shelling percent, Harvest index, Pod yield.

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Introduction

Groundnut (*Arachis hypogaea* L.) is an annual legume which is also known as peanut, earthnut and monkey-nut. It is the 13th most important food crop and 4th most important oilseed crop of the world. Groundnut seeds (kernels) contain 40-50% fat, 20-50% protein and 10-20% carbohydrate. Global climate change has emerged as an important environmental challenge due to its potential impact on biological systems of planet Earth. About 90% of the world's peanut production occurs in the tropical and semi-arid tropical regions, which are characterized by high temperature and low or erratic rainfall. In the tropics, most of the crops are near their maximum temperature tolerance therefore, crop yields may decrease even with minimal increases in temperature. The mean optimal air temperature range for vegetative growth of peanut is between 25 and 30 ^{0}C, which is warmer than the optimum range for reproductive growth, which is between 22 and 24 ^{0}C (Cox1979 and Ong 1984). Further, with present trends of global warming, temperatures are likely to become hotter, and increase in mean air temperature of 2-3 ^{0}C is predicted to reduce the groundnut yields by 23-36%. Hence, an attempt has been made to understand through the study effect of temperature stress on yield and yield components of groundnut (*Arachis hypogaea* L.) genotypes.

Materials and Methods

The field experiment was conducted at Main Ag-

Table 1. Weekly meteorological data at Main Agricultural Research Station (MARS) UAS Dharwad for 2015 during crop growth period. MSW : Meteorological Standard Week.

MSW	Week days	Max temp (^{0}C)	Min temp (^{0}C)
23	4 Jun - 10 Jun	31.2	21.0
24	11 Jun - 17 Jun	29.9	21.3
25	18 Jun - 24 Jun	26.1	21.0
26	25 Jun - 1 Jul	28.0	21.5
27	2 Jul - 8 Jul	29.2	20.9
28	9 Jul - 15 Jul	29.6	22.2
29	16 Jul - 22 Jul	28.8	21.3
30	23 Jul - 29 Jul	27.7	20.7
31	30 Jul - 5 Aug	28.4	20.4
32	6 Aug - 12 Aug	27.7	20.8
33	13 Aug - 19 Aug	29	20.7
34	20 Aug -26 Aug	29.9	20.6
35	27 Aug - 2 Sep	28.6	20.3
36	3 Sep - 9 Sep	30.1	20.4
37	10 Sep - 16 Sep	28.4	20.6
38	17 Sep - 23 Sep	28.8	20.6
39	24 Sep - 30 Sep	36.7	20.9
40	1 Oct - 7 Oct	29.7	20.4
41	8 Oct - 14 Oct	30.2	20.5
42	15 Oct - 21 Oct	32.4	19.3
43	22 Oct - 28 Oct	32.2	17.9
44	29 Oct - 4 Nov	30.9	20.0

ricultural Research Station (MARS), University of Agricultural Sciences, Dharwad during *kharif,* 2015-16. The experiment consisted of 4 genotypes (TMV-2, G2-52, Dh-86 and Dh-216) with 4 different dates of sowing from D_1, D_2, D_3 and D_4 temperature regimes (23[nd], 26[th], 29[th] and 32[nd] standard meteorological week), laid in a factorial RBD. The mean maximum temperature (36.7 ^{0}C) was recorded under 39[th] standard week (24[th]–30[th] Sep) followed by (32.4 ^{0}C) under 42[nd] standard week (15[th]-21[st] October), from 41[st] standard week to 44[th] standard weeks were found to be hottest weeks. Minimum temperature ranged from 17.9 to 22.2 ^{0}C during cropping period, 2015. Weekly distribution of Meteorological data viz. T_{max} and T_{min} temperature (^{0}C) was presented in Table 1. During croping period crop was experienced terminal heat stress (at harvest). The observation on yield and yield components viz., number of pods per plant, number of seeds per plant, pod weight, seed weight, haulm weight, shelling percentage, test weight, harvest index and pod yield were recorded as follows.

Five plants tagged earlier for recording various morphological observations were harvested at physiological maturity to record the data on yield and yield components as per standard procedures.

Table 2. Effect of temperature regimes on number of pods per plant, number of seeds per plant, pod weight per plant and seed weight (g plant^{-1}) in groundnut genotypes. D_1 : 31-05-2015 to 06-06-2015, D_2 : 21-06-2015 to 27-06-2015, D_3 : 12-07-2015 to 18-07-2015, D_4 : 02-08-2015 to 08-08-2015. DMRT : Values in the column followed by the same letter do not differ significantly (NS).

Treatments	No. of pods plant^{-1}	No. of seeds plant^{-1}	Pod weight plant^{-1}	Seed weight plant^{-1}
Dates of sowing (D)				
23[rd] Standard week (D_1)	15.75^{a}	27.25^{a}	14.02^{a}	10.67^{a}
26[th] Standard week (D_2)	14.08^{ab}	22.17^{ab}	11.19^{b}	8.43^{b}
29[th] Standard week (D_3)	12.08^{a}	18.42^{b}	10.76^{b}	7.42^{c}
32[nd] Standard week (D_4)	10.83^{b}	15.67^{b}	4.27^{c}	2.72^{d}
SEm ±	0.51	1.08	0.12	0.07
LSD @ 5%	1.46	3.12	0.35	0.20
Genotypes (G)				
TMV-2 (G_1)	10.92^{c}	15.92^{b}	7.00^{c}	5.22^{d}
G2-52 (G_2)	17.17^{a}	28.83^{a}	12.81^{a}	9.70^{a}
Dh-86 (G_3)	11.25^{bc}	20.17^{b}	10.09^{b}	7.48^{b}
Dh-216 (G_4)	13.42^{ab}	18.58^{b}	10.34^{b}	6.84^{c}
SEm ±	0.51	1.08	0.12	0.07
LSD @ 5%	1.46	3.12	0.35	0.20
Interactions (D × S)				
D_1G_1	12.33^{d-h}	19.67^{c-g}	10.88^{f}	8.57^{e}
D_1G_2	23.33^{a}	41.67^{a}	17.31^{a}	12.92^{a}
D_1G_3	12.33^{d-h}	24.33^{b-d}	15.20^{b}	12.01^{b}
D_1G_4	15.00^{c-f}	23.33^{e-e}	12.69^{d}	9.19^{d}
D_2G_1	11.00^{f-h}	17.00^{c-g}	8.75^{h}	6.24^{g}
D_2G_2	17.67^{bc}	30.33^{b}	14.15^{c}	11.25^{c}
D_2G_3	11.67^{ch}	21.00^{c-f}	10.1^{g}	7.59^{f}
D_2G_4	14.00^{c-g}	20.33^{c-g}	11.76^{e}	8.62^{e}
D_3G_1	09.00^{h}	13.67^{g}	5.34^{i}	4.05^{h}
D_3G_2	15.67^{c-e}	25.33^{bc}	14.58^{bc}	11.2^{c}
D_3G_3	16.00^{cd}	19.33^{c-g}	10.19^{g}	7.21^{f}
D_3G_4	21.00^{ab}	15.33^{f-g}	12.93^{d}	7.20^{f}
D_4G_1	10.67^{gh}	13.33^{g}	3.04^{k}	2,00^{j}
D_4G_2	12.00^{d-h}	18.00^{d-g}	5.20^{i}	3.43^{i}
D_4G_3	09.67^{b}	16.00^{fg}	4.87^{i}	3.10^{i}
D_4G_4	11.00^{f-h}	15.33^{fg}	3.98^{j}	2.33^{j}
SE m ±	1.24	2.16	0.24	0.14
LSD @ 5%	3.59	6.25	0.71	0.40

Results and Discussion

Yield is mutagenic trait, the reduction in yield was mainly attributed to reduction in its components (Tables 2 and 3) which are influenced by temperature, as temperature increases with delayed sowing number of pegs in groundnut cultivars were also increased, but

Table 3. Effect of temperature regimes on haulm weight, shelling percentage, test weight, harvest index and pod yield in groundnut genotypes. D_1 : 31-05-2015 to 06-06-2015, D_2 : 21-06-2015 to 27-06-2015, D_3 : 12-07-2015 to 18-07-2015, D_4 : 02-08-2015 to 08-08-2015. DMRT : Values in the column followed by the same letter do not differ significantly (NS).

Treatment	Haulm weight plant^{-1} (g)	Shelling (%)	Test weight (g)	HI (%)	Pod yield (kg ha^{-1})
Dates of sowing (D)					
23rd Standard week (D_1)	3.35^{a}	76.21^{a}	35.46^{a}	51.97^{a}	3504^{a}
26th Standard week (D_2)	2.77^{b}	74.82^{a}	33.46^{b}	44.5^{b}	3083^{a}
29th Standard week (D_3)	3.34^{a}	69.84^{b}	30.68^{c}	37.52^{c}	2058^{b}
32nd Standard week (D_4)	1.56^{c}	63.49^{c}	24.93^{d}	21.44^{d}	1211^{c}
SEm ±	0.07	0.31	0.07	0.68	93
LSD @ 5%	0.21	0.91	0.20	1.97	268
Genotypes (G)					
TMV-2 (G_1)	1.79^{c}	72.94^{ab}	28.89^{c}	31.19^{c}	1845^{c}
G2-52 (G_2)	3.11^{a}	74.28^{a}	32.36^{a}	43.86^{a}	3064^{a}
Dh-86 (G_3)	2.61^{b}	72.14^{b}	32.14^{a}	44.98^{a}	2612^{ab}
Dh-216 (G_4)	3.50^{a}	64.99^{c}	31.14^{b}	35.39^{b}	2334^{bc}
SEm ±	0.07	0.31	0.07	0.68	93
LSD @ 5%	0.21	0.91	0.20	1.97	268
Interactions (D × S)					
D_1G_1	2.31^{g}	78.77^{ab}	33.95^{f}	48.35^{c}	2409^{cd}
D_1G_2	4.39^{b}	74.64^{de}	37.45^{a}	53.34^{b}	4624^{a}
D_1G_3	3.19^{c-e}	79.01^{a}	35.45^{c}	58.48^{a}	3773^{b}
D_1G_4	3.50^{c}	72.42^{fg}	35.00^{d}	47.71^{cd}	3208^{b}
D_2G_1	2.51^{fg}	71.31^{g}	29.25^{j}	36.60^{f}	2491^{c}
D_2G_2	2.90^{ef}	79.51^{a}	36.20^{b}	49.17^{c}	3247^{b}
D_2G_3	2.51^{fg}	75.15^{c-e}	34.40^{e}	49.46^{bc}	3219^{b}
D_2G_4	3.14^{c-e}	73.30^{ef}	34.00^{f}	42.77^{e}	3374^{b}
D_3G_1	1.29^{ij}	75.89^{cd}	28.75^{k}	26.43^{h}	1593^{ef}
D_3G_2	3.38^{cd}	77.01^{bc}	30.25^{i}	48.56^{c}	2502^{c}
D_3G_3	2.98^{de}	70.76^{g}	32.70^{g}	44.06^{de}	2309^{cd}
D_3G_4	5.73^{a}	55.72^{k}	31.00^{h}	31.03^{g}	1828de
D_4G_1	1.04^{j}	65.79^{h}	23.60^{o}	13.40^{j}	888^{g}
D_4G_2	1.77^{h}	65.96^{h}	25.55^{m}	24.38^{h}	1884de
D_4G_3	1.77^{h}	63.66^{i}	26.00^{l}	27.93^{gh}	1148^{fg}
D_4G_4	1.65i	58.54^{j}	24.55^{n}	20.06i	924^{g}
SEm ±	0.14	0.63	0.14	1.36	185
LSD @ 5%	0.41	1.81	0.39	3.93	535

there was adverse effect on pod set (Talwar and Yanagihara 1999 and Ketring 1984). Prasad et al.(2003) further, reported that both pegging and podding were delayed above 32/22 to 36/26 ^{0}C temperature range and with increasing temperature from 32/22 to 44/34 ^{0}C pod number decreased from 353 to 74 m^{-1} and seed number decreased from 857 to 43 m^{-1}. Where from obtained data we noticed that highest number of pods per plant (15.75) and seeds per plant (27.25) was recorded under D_1 temperature regime and showed gradual reduction from D_1 to D_4 temperature regimes. Genotype, G2-52 recorded highest number of pods per plant as well as seeds per plant (17.17 and 28.83), followed by Dh-86 and Dh-216. Among interactions also G2-52 under D_1 temperature regime recorded maximum pods (23.33) and seed (41.67) numbers and least pod set (10.67) and seed set (13.33) was recorded by genotype TMV-2 under D_4 temperature regime. Similar results were also noticed by Awal and Ikeda (2002),.Banterng et al. (2003) and Prasad et al. (2006). It might be due to terminal drought and heat stress, which affect the number of pods as well as seeds per plant. It was noticed from correlation studies that number of pods per plant and number of seeds per plant (0.740** and 0.840**) significantly and positively correlated with yield of groundnut.

High air and soil temperatures have significant effect on fruit set and pod weight, whereas, combined treatment of high air and soil temperature reduced pod set and pod weight by 58 and 57% at podding, 49 and 52% at flowering, respectively was observed by Cox (1979), Ong (1984) and Prasad et al. (2000). These results were in conformity with present data, where number of pods and seed weight per plant was shown higher in D_1 temperature regime (14.02 and 10.67 respectively) and weights were found to be decreasing order with increasing temperature (4.27 and 2.72 under D_4 temperature regimes, respectively). Among genotypes G2-52 maintained higher pod and seed weight (12.81 and 9.70, respectively) compared to other 3 genotypes (TMV-2, Dh-86 and Dh-216). Under interaction effects, G2-52 under D_1 temperature regime recorded maximum pod and seed weight (17.31 and 12.92 g) and significantly least in D_4 temperature regime in all the genotypes. Thus, showed that delayed sowing (heat stress) reduced both pod and seed weight (Ketring 1984, Shravanakumar et al. 2014 and Mukesh 2015). It was also confirmed by correlation study, where pod weight and seed weight per plant showed positive correlation (0.867** and 0.898**) with yield of groundnut.

As temperature increases from 32/22 to 44/34 ^{0}C, shelling per cent decreases from 82 to 74% (0.7 units/^{0}C) Prasad et al. (2003). Thus, high temperature decreases the shelling percent (Craufurd et al. 2002) and 60 to 76% at 25/25 ^{0}C and 41 to 62% at 35/30 ^{0}C for groundnut genotypes (Rao et al. 1985 and Talwar and Yanagihara 1999). The data presented here was showed higher shelling per cent under D_1 temperature regime (76.21%) which was on par with D_2 temperature regime (74.82%) followed by D_3 and D_4 (69.84 and 63.49%) temperature regimes. Genotype, G2-52 recorded highest shelling percent (74.28%) irrespective of different temperature regimes. In interaction effect genotype Dh-86, G2-52 under D_1 and D_2 temperature regime recorded highest shelling per cent (79.01% and 79.51%), respectively. Thus from

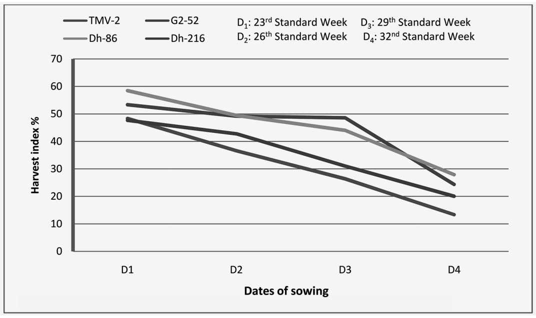

Fig. 1. Effcet of temperature regimes on harvest index of groundnut genotypes.

obtained results noticed that reduction in shelling percent which might be due to decrease in partitioning of dry matter to seed development (Craufurd et al. 2002). On other hand shelling per cent (0.660**, respectively) was positively correlated with yield of groundnut.

It was noticed from previous studies that harvest index was reduced by more than 59% at higher temperature 35/30 ^{0}C (Craufurd et al. 2002, Prasad et al. 2003, Kiniry et al. 2005 and Meena and Yadav 2015). Similar data was obtained in our investigation (Fig. 1), where highest test weight (g) and harvest index (%) was recorded under D_1 temperature regime (35.46 g and 51.97% respectively) and reduced gradually (58.7%) with delayed sowing. Both genotypes G2-52 and Dh-86 recorded maximum test weight and harvest index per cent (32.36 g, 43.86% and 32.4 g, 44.98% respectively). Among the interaction effects, genotype G2-52 under D_1 temperature regime recorded higher test weight (g) 37.45 and least by TMV-2 in D_4 temperature regime (23.60), where in, Dh-86 under D_1 temperature regime (58.48%) and TMV-2 under D_4 temperature regime (13.4%) recorded maximum and minimum harvest index per cent, respectively. It was noticed from correlation study that test weight and harvest index were highly positively correlated with yield of groundnut (0.913** and 0.890**) (Mukesh 2015, Muldon 2002, Naab et al. 2004).

Variation in pod yield ranging from 3,504 kg ha^{-1} to 1,211 kg ha^{-1} was noticed among the 4 temperature regimes (Fig. 2). The lowest pod yield 1,211 kg

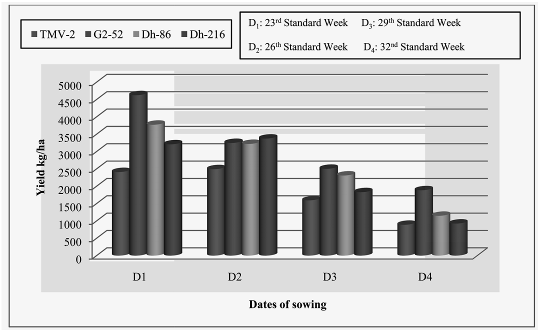

Fig. 2. Effect of different temperature regimes on pod yield of groundnut.

ha^{-1} was recorded under D_4 temperature regime and highest (3,504 kg ha^{-1}) under D_1 temperature regime, which was on par with D_2 temperature regime (3,083 kg ha^{-1}). Among the genotypes G2-52 recorded (3,064 kg ha^{-1}) significantly higher pod yield which was on par with Dh-86 (2,612 kg ha^{-1}) followed by Dh-216 (2,334 kg ha^{-1}) while TMV-2 (1,845 kg ha^{-1}) recorded lower pod yield. Among interaction effects, G2-52 under D_1 temperature regime recorded higher pod yield (4,624 kg ha^{-1}) compared to other interactions. These results are found to be similar to the results of several works (Prasad et al. 2000b, Frimpong 2004, Caliskan et al. 2008 and Kakani et al.2015) who observed that vegetative and reproductive period was longer for early / normal sown crop and was short for late planting. Thus, affects the yield and yields components of groundnut genotypes adversely. Yield and yield components like pods per plant, seeds per plant, pod weight, seed weight and haulm weight per plant, test weight, shelling percent, harvest index and yield were found to be optimum for genotype G2-52 under D_1 temperature regime (Reddy and Suresh 2001, Wheeler et al. 1997).

Current study confirmed that yield and yield components were highly influenced by temperature regimes. High temperature (heat stress) showed deteriorative effect on both vegetative and reproductive growth and thus results in reduced crop growth, partitioning efficiency and ultimately yield of the crop.

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