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RESEARCH PAPER

Effect of moisture stress on physiological mechanisms in drought tolerance in selected genotypes of groundnut (*Arachis hypogaea* L.)

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Abstract : Eight groundnut genotypes of including four released and pre-released genotypes were evaluated for moisture stress at pegging (M_2) and pod development (M_3) stage stress situations with control (M_1) during post-rainy season (Nov-April), 2018-19 at University of Agricultural Sciences, Dharwad and Karnataka, India. The drought stress was imposed by with holding irrigation at 40-80 DAS (M_2) and 80 DAS-harvest (M_3). Observations were recorded for physiological parameters like leaf area, SPAD readings, chlorophyll content, stomatal frequency, photosynthetic rate and pod yield per plant. Among the selected genotypes, GPBD-4, Dh-257 and Dh-256 are considered as drought tolerant genotypes at both the stress levels based on lesser reduction in leaf area, optimum chlorophyll content and photosynthetic rate, less leaf folding and by these adaptations recorded reduced reduction in pod yield over control. Genotypes, Dh-86 and TMV-2 affected severely by drought at both the stages. But higher effect was observed under pod developmental stage stress.

Key Words : Drought stress, Physiological parameters, Soil moisture stress, SPAD, Relative leaf chlorophyll content

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is important oilseed crop as its seed contains 44–56 per cent oil and 22–30 per cent protein on a dry seed basis. Among the environmental stresses, the drought stress at critical stages (flowering, pegging and pod filling) is the most important factors, which limits production of groundnut.

Flowering and pegging stages were considered as most sensitive ones, majority of reports reveal that pod development stage is the most sensitive to moisture (Ramachandrappa *et al.*, 1992) during which the demand of photosynthetic products for active sinks (pods) is higher. Soil water status of soil surface is critical to peg penetration. Pegs fail to penetrate effectively into hard and dry soil, especially in crusted soils. It is likely that within a few days of withholding water the soil surface becomes too dry for peg penetration. Once pegs are in the soil, adequate moisture and darkness are needed for

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pod development. Adequate moisture in the pod zone is critical for development of pegs into pods and adequate soil water in pod zone for the first 30 days of peg development. After 30 days of adequate moisture in the pod zone, pods can continue normal growth in dry soil if roots have adequate moisture.

Therefore, in present study the response of eight groundnut varieties to drought stress was investigated to evaluate their sensitivity to drought stress during pegging and pod development growth stages under field experiment.

MATERIAL AND METHODS

The experiment was laid in split plot with three replications and three treatments in groundnut crop. The seeds were sown on 16th November, 2018 by manually and to a depth of 2 to 3 cm. A spacing of 30 cm between rows and 10 cm from plant to plant was maintained. The observations were recorded at 30 DAS, 60 DAS and 90 DAS and at harvest to evaluate the effect of water stress at different growth stages on various physiological characters.

Leaf area was measured by leaf disc method and expressed as cm^2 per plant. For this purpose, 25 leaf discs of known diameter was taken from all over the canopy at 30, 60, 90 DAS and at harvest and dried in oven at 80^oC to constant weight. After complete drying their dry weight was recorded accurately, rest of the leaves from the plant are separated oven dried similarly at 80^oC to a constant weight. From the area and dry weight of the discs, the leaf weight per plant, the leaf area per plant was calculated.

The chlorophyll meter or SPAD meter is a simple, portable diagnostic tool that measures the greenness or relative chlorophyll content of leaves (Inada, 1963 and 1985 and Kariya *et al.*, 1982). Chlorophyll-a, chlorophyll-b and total chlorophyll contents were calculated using the method given by Shoaf and Lium (1976). Observations on photosynthetic rate was recorded using IRGA (Infra-red gas analyser). Terminal leaflets from the third leaf from the top on the stem was used for sampling. Leaflets were coated with 30 per cent solution of thermocol in xylol on both surfaces. After drying, the impressions were peeled off for taking stomatal frequency.

RESULTS AND DISCUSSION

Soil moisture reduced gradually under stressed plots till harvest due to the with holding of irrigation. Drought stress at two different growth stages altered many physiological characters. The outcome of present experiment are presented in Table 1, 2 and 3. Control recorded superior values for all the physiological parameters. Leaf area is one of the important parameter, as it serve as a photosynthetically active source and considered as an important functional unit of plant which contributes to the growth and formation of yield. Drought significantly triggers leaf area mainly because of reduction in leaf number and leaf expansion. In present study, higher leaf area recorded in control, M_1 (29.29 dm^2 $plant^{-1}$), while significantly higher reduction observed under M_3 stress stages (16.47 dm^2 $plant^{-1}$). Among the genotypes, Dh-257 and Dh-256 recorded higher leaf area irrespective of stress levels, whereas TMV-2 recorded lowest leaf area at all the stress and growth stages. These results were on par with Madukwe *et al.* (2011) and Borkar and Dharanguttikar (2014).

SPAD readings represents nitrogen content, which in turn indicates chlorophyll content in leaf. In present study, SPAD and chlorophyll content increased during pegging stage stress (Nigam and Rupakula, 2008). Chlorophyll content increases when stress occurs at pegging stage due to minimal reduction in leaf water potential under stress and higher photosynthetic machinery occurs in genotypes with lower specific leaf area machinery (Nageswara Rao *et al*., 2001). Higher SPAD, chlorophyll 'a', chlorophyll 'b' and total chlorophyll recorded in M_2 (50.14, 2.04, 0.55 and 2.59 mg g^{-1} fr. wt, respectively), while lowest recorded in M_1 (42.02,1.51,0.32 and 1.83 mg g^{-1} fr. wt, respectively) at 60 DAS. Genotypes, Dh-257, Dh-256 and GPBD-4 recorded higher increase, while TMV-2 and Dh-86 shown lower increase in chlorophyll content at 60 DAS.

Under terminal drought stress chlorophyll content decreases mainly because of destruction or reduced development of chloroplast. Higher SPAD, chlorophyll 'a', chlorophyll 'b' and total chlorophyll recorded in M_1 (4.37, 1.66, 0.34 and 2.0 mg g^{-1} fr. wt, respectively), while M_3 (31.0, 0.9, 0.16 and 1.06 mg g^{-1} fr. wt, respectively) recorded lowest chlorophyll content at 90 DAS. Among Genotypes, Dh-257, Dh-256 and GPBD-4 recorded lowest reduction in chlorophyll content under terminal stress compared to control, while TMV-2 and Dh-86 recorded higher reduction in chlorophyll content at 90 DAS which is mainly because of severe destruction of chloroplast. These results were on par with Chakraborty

Table 1: Effect of soil moisture stress at different growth stages on leaf area (dm^2 $plant^{-1}$) and pod yield (kg ha^{-1}) of groundnut genotypes

Treatments	Leaf area				Pod yield
M: Moisture stress levels	30 DAS	60 DAS	90 DAS	Harvest	
$M_{1:}$ Control	2.98	9.83^{a}	23.22^{a}	29.29^{a}	3033^{a}
$M_{2:}$ Pegging stage	2.81	6.10^{c}	17.43^{b}	23.64^{b}	2644^{b}
$M_{3:}$ Pod dev. stage	2.74	8.83^{b}	12.02^{c}	16.47^{c}	1037^{c}
LSD @ 5%	NS	0.52	0.92	0.94	124.2
G: Genotypes					
V_1- GPBD-4	3.25^{c}	10.88^{a}	17.28^{d}	23.76^{d}	2374^{d}
V_2- G2-52	4.34^{a}	9.46^{bc}	14.12^{f}	20.60^{f}	2016^{e}
V_3- Dh-86	2.80^{d}	7.03^{d}	19.27^{c}	22.70^{e}	1671^{f}
V_4- TMV-2	2.41^{e}	6.77^{d}	8.48^{g}	12.65^{g}	1254^{g}
V_5- Dh-245	3.85^{b}	9.99^{b}	17.61^{d}	25.54^{c}	2126^{e}
V_6- Dh-232	1.87^{f}	6.15^{e}	16.23^{e}	22.60^{e}	2537^{c}
V_7- Dh-256	1.79^{f}	6.85^{d}	23.14^{b}	29.43^{a}	2845^{b}
V_{8-} Dh-257	2.46^{e}	8.91^{c}	24.32^{a}	27.79^{b}	3082^{a}
LSD @ 5%	0.13	0.58	0.51	0.49	162.4
M×G: Interaction					
M_IV_1	3.40^{cd}	11.12^{bc}	26.07^{c}	32.63^{b}	3083^{c}
M_IV_2	4.69^{a}	10.54^{cd}	23.39^{d}	29.94^{d}	2829^{c}
M_IV_3	3.03^{ef}	9.24^{e-g}	28.02^{a}	31.72^{c}	2517^{c}
M_IV_4	2.16^{hi}	9.67^{d-g}	10.14^{h}	17.76^{i}	1980^{d}
M_IV_5	4.62^{a}	13.23^{a}	27.37^{ab}	33.92^{a}	2857^{e}
M_IV_6	1.82^{j-l}	5.94^{ij}	20.92^{e}	27.47^{e}	3394^{cb}
M_IV_7	1.87^{jk}	9.01^{fg}	23.34^{d}	29.61^{d}	3683^{ab}
M_IV_8	2.28^{h}	9.92^{d-f}	26.50^{bc}	31.28^{c}	3923^{a}
M_2V_1	3.22^{de}	8.78^{g}	17.49^{f}	24.04^{g}	2815^{c}
M_2V_2	3.59^{c}	6.10^{ij}	9.87^{hi}	16.42^{j}	2274de
M_2V_3	2.82^{f}	4.39^{k}	20.83^{e}	27.38^{e}	2078^{e}
M_2V_4	2.99^{ef}	4.23^{k}	8.15^{j}	11.22^{m}	1443^{fg}
M_2V_5	3.06^{ef}	6.86^{hi}	15.57^{g}	26.47^{f}	2501^{d}
M_2V_6	1.80^{kl}	6.59^{hi}	18.29^{f}	24.50^{g}	2995^{c}
M_2V_7	1.90^{jk}	5.27^{jk}	23.06^{d}	29.49^{d}	3417^{b}
M_2V_8	3.10^{e}	6.59^{hi}	26.17^{c}	29.57^{d}	3627^{b}
M_3V_1	3.14^{e}	12.75^{a}	8.27^{j}	14.62^{l}	1222^{gh}
M_3V_2	4.73^{a}	11.74^{b}	9.09^{ij}	15.43^{kl}	944^{h}
M_3V_3	2.53^{g}	7.47^{h}	8.98^{ij}	8.99^{n}	419^{i}
M_3V_4	2.08^{h-j}	6.40^{h-i}	7.16^{k}	8.97^{n}	341^{i}
M_3V_5	3.86^{b}	9.89^{d-g}	9.90^{hi}	16.23^{jk}	1022^{h}
M_3V_6	2.00^{i-k}	5.93^{ij}	9.48^{hi}	15.81^{jk}	1222^{gh}
M_3V_7	1.60^{l}	6.26^{ij}	23.02^{d}	29.17^{d}	1434^{fg}
M_3V_8	2.00^{i-k}	10.22^{d-e}	20.28^{e}	22.52^{h}	1694^{f}
LSD @ 5%	0.23	1.01	0.89	0.84	281.4

Note: Alphabets in the column followed by the same letter do not differ significantly as per the DMRT NS= Non-significant

Table 2: Effect of soil moisture stress at different growth stages on chlorophyll 'a' (mg g^{-1} fr. wt.), chlorophyll 'b' (mg g^{-1} fr. wt.) and total chlorophyll (mg g^{-1} fr. wt.) of groundnut genotypes

Treatments	Chlorophyll 'a'			Chlorophyll 'b'			Total chlorophyll		
M: Moisture stress levels	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
$M_{1:}$ Control	1.00	1.51^{b}	1.66^{a}	0.23	0.32^{b}	0.34^{b}	1.23	1.83^{b}	2.00^{a}
$M_{2:}$Pegging stage	1.02	2.04^{a}	1.28^{b}	0.22	0.55^{a}	0.58^{a}	1.24	2.59^{a}	1.86^{b}
$M_{3:}$ Pod Dev. stage	1.01	1.41^{c}	0.90^{c}	0.23	0.29^{b}	0.16^{c}	1.24	1.70^{c}	1.06^{c}
LSD @ 5%	NS	0.08	0.11	NS	0.11	0.08	NS	0.08	0.11
V: Genotypes									
V_1- GPBD-4	0.78^{de}	1.55^{c}	1.36^{c}	0.16^{d}	0.25^{f}	0.31^{c}	0.93^{g}	1.80^{d}	1.67^{cd}
V_2- G2-52	1.04^{bc}	1.68^{b}	1.17^{e}	0.15^{d}	0.32^{d}	0.47^{b}	1.19^{e}	2.00^{c}	1.63^{de}
V_3- Dh-86	0.76^{e}	1.42^{de}	1.01^{f}	0.31^{a}	0.29^{de}	0.36^{c}	1.07^{f}	1.71^{d}	1.36^{f}
V_4- TMV-2	1.07^{b}	1.68^{b}	0.93^{g}	0.28^{a-c}	0.41^{c}	0.19^{d}	1.36^{b}	2.08^{c}	1.12^{g}
V_5- Dh-245	1.06^{b}	1.50^{cd}	1.28^{d}	0.26^{bc}	0.27ef	0.28^{cd}	1.32^{c}	1.77^{d}	1.56^{e}
V_6- Dh-232	0.91^{cd}	1.34^{e}	1.37^{c}	0.14^{d}	0.25^{f}	0.37^{c}	1.04^{f}	1.59^{e}	1.74^{bc}
V_7- Dh-256	0.98^{bc}	1.74^{b}	1.49^{b}	0.25^{c}	0.45^{b}	0.34^{c}	1.23^{d}	2.19^{b}	1.82^{b}
V_{8-} Dh-257	1.48^{a}	2.34^{a}	1.61^{a}	0.29^{ab}	0.82^{a}	0.58^{a}	1.77^{a}	3.16^{a}	2.19^{a}
LSD @ 5%	0.13	0.10	0.03	0.03	0.03	0.09	0.03	0.09	0.09
M×V: Interaction									
M_IV_1	0.82^{f-j}	1.47^{hi}	1.87^{a}	0.17^{b}	0.25^{ij}	0.24^{e-i}	0.99^{kl}	1.72^{jk}	2.11^{bc}
M_IV_2	0.92^{d-j}	1.68^{e-g}	1.70^{bc}	0.14^{b}	0.33^{g}	0.36^{d-f}	1.06^{ij}	2.01^{hi}	2.06^{bc}
M_IV_3	0.82^{f-j}	1.17^{jk}	1.45^{g}	0.27^{ab}	0.22^{ij}	0.25^{e-i}	1.09^{hi}	1.39^{lm}	1.70^{d}
M_IV_4	1.05^{c-g}	1.54^{gh}	1.55^{f}	0.27^{ab}	0.32^{gh}	0.13^{hi}	1.32^{e}	1.86^{ij}	1.68^{d}
M_IV_5	0.90^{e-j}	1.21^{jk}	1.60^{ef}	0.30^{ab}	0.14^{k}	0.35^{d-f}	1.20^{f}	1.35^{m}	1.95^{c}
M_IV_6	0.99^{c-i}	0.98^{l}	1.74^{b}	0.18^{b}	0.12^{k}	0.34^{d-g}	1.14^{gh}	1.11^{n}	2.08^{bc}
M_IV_7	0.96^{c-j}	1.65^{fg}	1.64^{de}	0.24^{b}	0.36^{e-g}	0.34^{d-g}	1.20^{f}	2.01^{hi}	1.98^{c}
M_IV_8	1.55^{a}	2.39^{a}	1.69^{b-d}	0.30a^{b}	0.79^{b}	0.71^{ab}	1.85^{a}	3.18^{b}	2.40^{a}
M_2V_1	0.78^{g-j}	1.90^{cd}	1.12^{k}	0.16^{b}	0.39^{d-f}	0.49^{cd}	0.94^{lm}	2.29^{ef}	1.61^{d}
M_2V_2	1.19^{b-d}	2.02^{c}	1.30^{i}	0.16^{b}	0.42^{d}	0.79^{a}	1.35^{e}	2.44^{e}	2.09^{bc}
M_2V_3	0.71^{j}	1.92^{cd}	0.88^{mn}	0.22^{b}	0.44^{d}	0.67^{ab}	0.93^{m}	2.36^{ef}	1.55^{d}
M_2V_4	1.15^{c-e}	2.20^{b}	0.92^{m}	0.30^{ab}	0.63^{c}	0.39^{de}	1.45^{d}	2.83^{c}	1.31^{e}
M_2V_5	1.08^{c-f}	2.25^{ab}	1.36^{h}	0.26^{ab}	0.41^{de}	0.30^{e-h}	1.34^{e}	2.66^{d}	1.66^{d}
M_2V_6	0.81^{f-j}	1.85^{c-e}	1.35^{hi}	0.14^{b}	0.41^{de}	0.64^{a-c}	0.95^{lm}	2.26^{fg}	1.99^{c}
M_2V_7	1.04^{c-g}	1.81^{d-f}	1.60^{ef}	0.27^{ab}	0.65^{c}	0.59^{bc}	1.31^{e}	2.46^{e}	2.19^{b}
M_2V_8	1.41^{ab}	2.40^{a}	1.66^{cd}	0.26^{ab}	1.03^{a}	0.78^{a}	1.67^{c}	3.44^{a}	2.44^{a}
M_3V_1	0.74^{ij}	1.29^{j}	1.08^{k}	0.14^{b}	0.11^{k}	0.19^{f-i}	0.85^{n}	1.40^{lm}	1.27^{ef}
M_3V_2	1.02^{c-h}	1.34^{ij}	0.50^{p}	0.15^{b}	0.20^{j}	0.25^{e-i}	1.17^{fg}	1.54^{l}	0.75^{h}
M_3V_3	0.75^{h-j}	1.16^{jk}	0.69^{o}	0.44^{a}	0.22^{ij}	0.15^{g-i}	1.20^{f}	1.38^{lm}	0.84^{h}
M_3V_4	1.03^{c-g}	1.29^{j}	0.32^{q}	0.27^{ab}	0.27^{hi}	0.06^{i}	1.30^{e}	1.56^{kl}	0.38^{i}
M_3V_5	1.20^{bc}	1.03^{kl}	0.86^{n}	0.23^{b}	0.26^{i}	0.19^{f-i}	1.43^{d}	1.29^{m}	1.05^{g}
M_3V_6	0.91^{e-j}	1.18^{jk}	1.01^{l}	0.11^{b}	0.23^{ij}	0.12^{hi}	1.03^{jk}	1.41^{lm}	1.13^{fg}
M_3V_7	0.94^{c-j}	1.76^{d-f}	1.21^{j}	0.23^{b}	0.35^{fg}	0.08^{i}	1.18^{fg}	2.11^{gh}	1.29^{ef}
M_3V_8	1.48^{a}	2.21^{b}	1.48^{g}	0.30^{ab}	0.65^{c}	0.24^{e-i}	1.78^{b}	2.86^{c}	1.72^{d}
LSD @ 5%	0.23	0.16	0.05	0.16	0.05	0.16	0.05	0.16	0.16

Note: Alphabets in the column followed by the same letter do not differ significantly as per the DMRT NS= Non-significant

Table 3: Effect of soil moisture stress at different growth stages on relative chlorophyll content of greenness (SPAD values) stomatal frequency (No's mm^{-2}) and photosynthetic rate (μ mol CO_2 m^{-2} sec^{-1}) of groundnut genotypes

Treatments	SPAD values			Stomatal frequency			Photosynthetic rate		
M: Moisture stress levels	30 DAS	30 DAS	60DAS	30 DAS	60DAS	90DAS	30 DAS	60DAS	90DAS
M_1: Control	30.25	155.8	324.6^{b}	155.8	324.6^{b}	421.1^{c}	26.63	28.14^{a}	23.20^{a}
M_2:Pegging stage	30.68	152.5	355.8^{a}	152.5	355.8^{a}	487.3^{b}	26.39	25.64^{b}	20.90^{b}
M_3: Pod Dev. stage	31.03	160.6	331.9^{b}	160.6	331.9^{b}	531.6^{a}	26.89	29.65^{a}	17.21^{c}
LSD @ 5%	NS	NS	8.53	NS	8.53	6.11	NS	2.13	1.04
V: Genotypes									
V_1- GPBD-4	31.27^{a}	45.50^{c}	36.56^{b}	147.8^{c}	320.3^{e}	457.7^{e}	27.37^{bc}	28.11^{d}	21.33^{b}
V_2- G2-52	26.21^{h}	42.33^{d}	31.97^{f}	156.8^{b}	346.9^{a}	493.7^{b}	28.26^{b}	27.32^{e}	18.93^{e}
V_3- Dh-86	28.55^{g}	48.50^{b}	36.58^{b}	160.8^{ab}	344.0^{ab}	500.9^{a}	26.45^{c}	26.24^{f}	20.58^{c}
V_4- TMV-2	31.1^{e}	41.27^{de}	34.46^{d}	146.9^{c}	339.0^{bc}	500.3^{a}	31.79^{a}	24.88^{g}	18.65^{e}
V_5- Dh-245	32.07^{c}	40.89^{e}	32.47^{e}	157.5^{b}	330.6^{d}	479.8^{c}	25.20^{d}	28.79^{b}	20.06^{d}
V_6- Dh-232	30.31^{f}	49.93^{a}	34.98^{c}	160.5^{ab}	335.2^{cd}	443.9^{f}	24.81^{de}	28.38^{cd}	20.33^{cd}
V_7- Dh-256	31.58^{d}	45.16^{c}	36.40^{b}	163.4^{a}	339.1^{bc}	473.2^{d}	23.96^{e}	28.61^{bc}	21.26^{b}
V_8- Dh-257	34.07^{b}	48.53^{b}	42.08^{a}	156.5^{b}	344.4^{ab}	490.7^{b}	25.26^{d}	30.15^{a}	22.36^{a}
LSD @ 5%	0.23	1.26	0.48	3.92	6.45	5.51	0.10	0.32	0.40
M×V: Interaction									
M_IV_1	31.39^{gh}	41.34^{ij}	40.71^{e}	145.2^{hi}	314.7^{jk}	411.8^{l}	26.57^{b-d}	28.08^{hi}	23.14^{d}
M_IV_2	25.03^{q}	39.73^{jk}	39.13^{f}	156.4^{c-f}	324.5^{h-k}	415.8^{kl}	28.59^{b}	27.74^{i}	22.80^{de}
M_IV_3	29.11^{m}	48.16^{cd}	47.44^{b}	160.4^{a-d}	322.5^{h-k}	413.8^{kl}	25.23^{b-f}	26.75^{jk}	21.80^{fg}
M_IV_4	29.40^{lm}	38.13^{k}	37.56^{g}	146.5^{g-i}	312.7^{k}	407.9^{l}	27.33^{bc}	26.41^{k}	21.46^{gh}
M_IV_5	31.10^{hi}	35.01^{l}	34.49^{hi}	157.4^{b-f}	320.6^{i-k}	431.6^{ij}	27.59^{bc}	29.09^{ef}	24.16^{b}
M_IV_6	30.90^{ij}	49.97^{bc}	46.64^{b}	160.4^{a-d}	326.5^{h-j}	395.0^{m}	26.61^{b-d}	28.12^{hi}	23.18^{d}
M_IV_7	32.18^{e}	44.45^{gh}	43.78^{c}	163.4^{a-c}	333.4^{f-h}	437.6^{i}	24.88^{d-f}	28.83^{fg}	23.90^{bc}
M_IV_8	32.89^{d}	47.36^{d-f}	49.21^{a}	156.4^{c-f}	342.2^{d-g}	455.4^{h}	26.23^{c-e}	30.09^{cd}	25.16^{a}
M_2V_1	31.89^{ef}	51.87^{ab}	35.24^{h}	145.5^{hi}	326.5^{h-j}	455.4^{h}	27.52^{bc}	26.40^{k}	22.23^{ef}
M_2V_2	25.93^{p}	45.45^{f-h}	29.50^{n}	153.3^{d-g}	371.7^{b}	510.8^{d-f}	27.85^{bc}	24.72^{l}	20.12^{i}
M_2V_3	27.02^{o}	52.67^{a}	32.51^{k}	157.2^{b-f}	360.9^{bc}	526.7^{c}	26.81^{b-d}	23.47^{m}	23.39^{cd}
M_2V_4	30.79^{i-k}	46.65^{d-g}	33.73^{ij}	143.6^{i}	391.4^{a}	516.8^{cd}	33.76^{a}	22.06^{n}	19.35^{j}
M_2V_5	33.38^{c}	52.47^{a}	31.81^{k-m}	153.2^{d-g}	354.4^{cd}	481.1^{g}	23.76^{f}	26.44^{k}	18.76^{jk}
M_2V_6	29.60^{l}	51.89^{ab}	31.41^{lm}	156.1^{c-f}	348.5^{de}	422.7^{jk}	23.66^{f}	27.14^{j}	21.49^{gh}
M_2V_7	31.83^{ef}	47.54^{d-f}	33.51^{j}	159.0^{b-e}	344.5^{d-f}	481.1^{g}	23.25^{f}	26.40^{k}	20.74^{hi}
M_2V_8	35.04^{a}	52.57^{a}	41.81^{d}	152.3^{e-h}	348.5^{de}	503.9^{ef}	24.52^{ef}	28.50^{gh}	21.14^{gh}
M_3V_1	30.52^{jk}	43.29^{hi}	33.73^{ij}	152.7^{d-h}	319.8^{i-k}	505.9^{ef}	28.02^{bc}	29.84^{d}	18.61^{k}
M_3V_2	27.68^{n}	41.81^{ij}	27.29^{o}	160.8^{a-d}	344.5^{d-f}	554.4^{b}	28.35^{b}	29.50^{de}	13.86^{o}
M_3V_3	29.54^{l}	44.67^{gh}	29.80^{n}	164.9^{ab}	348.5^{de}	562.3^{b}	27.31^{bc}	28.50^{gh}	16.54^{m}
M_3V_4	33.33^{c}	39.03^{k}	32.10^{kl}	150.6^{f-i}	312.8^{k}	576.2^{a}	34.27^{a}	26.16^{k}	15.14^{n}
M_3V_5	31.72^{fg}	35.19^{l}	31.10^{m}	161.8^{a-c}	316.8^{jk}	526.7^{c}	24.26^{f}	30.85^{b}	17.26^{l}
M_3V_6	30.43^{k}	47.93^{c-e}	26.88^{o}	164.9^{ab}	330.7^{g-i}	513.8^{de}	24.16^{f}	29.88^{d}	16.32^{m}
M_3V_7	30.72^{i-k}	43.49^{hi}	31.90^{k-m}	167.9^{a}	339.6^{e-g}	500.9^{f}	23.75^{f}	30.59^{bc}	19.14^{jk}
M_3V_8	34.27^{b}	45.66^{e-h}	35.22^{h}	160.8^{a-d}	342.5^{d-g}	512.8^{de}	25.02^{d-f}	31.85^{a}	20.79^{hi}
LSD @ 5%	0.4	2.18	1.72	6.79	11.18	9.55	1.73	0.55	0.68

Note: Alphabets in the column followed by the same letter do not differ significantly as per the DMRT NS= Non-significant

et al. (2015); Saravanan *et al.* (2018) and Shinde *et al*. (2017).

Stomatal frequency is one of the important parameter to assess drought tolerance in groundnut genotypes, stomata per unit area increases during stress condition this is mainly because that the ration number of stomata per unit epidermal cell is predetermined, but size of the cell is reduced under stress without affecting this ratio. Due to this stomata per unit leaf area increases because of leaf folding and overlapping of cells but total stomata per leaf area reduces severely. In present experiment, significantly highest stomatal frequency recorded in M_3 (531.6 No's mm^{-2}), whereas M_2 (487.3 No's mm^{-2}) recorded comparatively less leaf folding over control M_1 (421.1 No's mm^{-2}) at harvest. Among genotypes, TMV-2 at terminal stress recorded highest stomatal frequency (576.2 No's mm^{-2}), while in control it has recorded stomatal frequency of 407.9 No's mm^{-2}. Genotypes, Dh-257 didn't shown higher increase under M_2 (481.1 No's mm^{-2}) and M_3 (500.9 No's mm^{-2}) over control (437.6 No's mm^{-2}). Similar results were recorded by Badigannavar *et al*.(1999) and Kalariya *et al*. (2017).

Photosynthetic rate is one of the important trait in assessing drought tolerance of a genotype. As, it directly reflects the productivity of crop. Drought stress causes stomata closure, which leads to the decreased CO_2 intake, affecting the rate of photosynthesis and consequently reduces growth and yield. In contrast, drought stress at post-flowering stage, leaf net photosynthesis declined to 66 per cent under the same conditions (Chastain *et al.*, 2016). Moisture stress leads to a significant reduction in net photosynthesis because of stomatal closure and reduced transpiration, which restricts the diffusion of CO_2 into the leaf and reduction in CO_2 fixation which leads to decreased $NADP^+$ regeneration during the Calvin cycle, which will reduce the activity of the photosynthetic electron transport chain. In the present experiment, M_1 (79.04%) recorded highest photosynthetic rate, while M_3 (69.52%) recorded lowest. Among genotypes, Dh-257 (77.37%) recorded highest photosynthetic rate, whereas TMV-2 (66.28%) recorded lowest photosynthetic rate irrespective of growth stages. Similar result were also recorded by Chakraborty *et al*. (2015).

Because of inability of groundnut to sustain pod development stage stress highest pod yield reduction was observed under M_3 (1037 kg ha^{-1}) stress, whereas pegging stage stressed plot tolerated stress with mentioned physiological adaptations and recorded significantly less reduction in yield *i.e.*, 2644 kg ha^{-1} over control 3033 kg ha^{-1}. Among genotypes, Dh-257 (3082 kg ha^{-1}) recorded significantly highest pod yield followed by Dh-256 (2845 kg ha^{-1}) and Dh-232 (2537 kg ha^{-1}) whereas TMV-2 (1254 kg ha^{-1}) recorded significantly lowest pod yield (Table 1). The results were in accordance with Vorasoot *et al*. (2003).

Canclusion:

In the present study, significant difference occurred between moisture levels, genotypes and their interactions at 30, 60, 90 DAS and at harvest. Control was superior for all the physiological characters followed by M_2 but M_3 has shown poor performance with respect to leaf area, SPAD readings, chlorophyll content, stomatal frequency, photosynthetic rate and pod yield per plant. Stressed plants shown reduced photosynthetic rate, chlorophyll content and SPAD values at both pegging and pod development stage stress. Decrease was statistically higher under pod development stage than at pegging stage. With these mechanisms the genotypes like Dh-257, GPBD-4 and Dh-256 are considered as drought tolerant genotypes.

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