Effect of moisture regimes and gypsum levels on growth and yield of *rabi* Groundnut (Arachis hypogea L.)

ABSTRACT

A field experiment was conducted in groundnut at Krishi vignan Kendra, Palem, Nagarkurnool during *rabi* 2021 to study the effect of moisture regimes and gypsum levels on growth and yield of *rabi* groundnut (*Arachis hypogea* L.). Among three moisture regimes, I_3 (1.0 IW/CPE) recorded significantly higher values of growth parameters: plant height (27.87cm), number of branches plant^{-1} (14.20), leaf area (174.06cm^2 plant^{-1}) and dry matter production (2711.67 kg ha^{-1}), which is on par with I_2 (0.8 IW/CPE)of plant height, number of branches plant^{-1}, leaf area at harvest and dry matter production at 90 DAS(days after sowing)and at harvest and yield attributes pod yield(review the redaction of the underlined sentence)(2337.68 kg ha^{-1}), halum yield (1659.06 kg ha^{-1}) compared to other treatments.In case of gypsum levels, gypsum at 600 kg ha^{-1}showed significantly higher values of growth parameters:plant height (28.93 cm), number of branches plant^{-1} (15.85), leaf area (194.66 cm^2 plant^{-1}) and dry matter production (3038.22 kg ha^{-1}) which is on par with I_2 (0.8 IW/CPE) of plant height, number of branches plant^{-1} at 60 DAS and yield attributes pod yield (2829.78 kg ha^{-1}) and haulm yield (1752.22 kg ha^{-1})which is followed by I_2 (0.8 IW/CPE)(you already mentioned it)and I_1(0.6 IW/CPE).The interaction of moisture regimes and gypsum level I_3 (1.0 IW/CPE) and G_4 (600 kg ha^{-1}) showed significantly higher values of dry matter production (1456.0 cm^2 plant^{-1})at 60 DAS, pod yield (3056.4 kg ha^{-1}) and halum yield (1956.0 kg ha^{-1}) over other treatments.

Briefly describe the experimental protocol: doses, repetitions, ...

Explain the symbols designating the moisture regime.

Review the redaction and cut long sentences into shorter ones.

Keywords:*moisture regimes, gypsum levels, groundnut.*

1. INTRODUCTION

Groundnut is an important oil and protein source to a large portion of the population in India. It is an annual, herbaceous legume and considered as king of vegetable oilseed crops in India and occupies a pre-eminent position in national edible oil economy(reference). Groundnut seed contains 47-53 % oil, 26 % protein and 11.5 % starch(reference). It is currently grown in an area of 21.8 million hectares over the globe (2021). India, China and the United States of America are the leading producers since last 25 years and account for 70% of the area in the world(reference). In India, it is grown on an area of about 4.82 million ha with a total production of 9.95 milliontonnes and productivity of 2.06 tonnes ha^{-1} during 2019-20. In Telangana, it occupies an area of 0.11 million ha with total production of 0.26 milliontonnes and productivity of 2.39 tonnes ha^{-1} in 2019-20Indiastat [1].

Cultivation of groundnut under rainfed conditions and imbalanced nutrient management are the main reasons for low productivity of groundnut. Irrigation water, a crucial input in crop production is scarce and expensive. Resource efficient use of this input is essential which can be achieved through judicious water management practices. Adequate and timely supply of water is essential for higher yields. Keeping the total quantity of irrigation water constant, increasing the frequency of irrigation would maximize the yields in several crops. There is possibility to double the groundnut yields during *rabi* season over *kharif* with limited number of irrigations. Because of high productivity under assured irrigation, a climatological approach based on IW/CPE ratio (IW-irrigation water, CPE - cumulative pan evaporation) in irrigation scheduling has been found most appropriate as it integrates most of the weather parameters which determine the water requirement of a crop and increase production by at least 15 to 20 %. Scheduling of irrigation based on IW/CPE depends on both available water holding capacityof soil and climatic parameters.

To ensure increased yields *of rabi* groundnut in traditional areas of Telangana, it is necessary to have a thorough understanding of the changes in the soil-plant-water relations and various morpho-physiological processes in relation to scheduling of irrigation water. Studies on various aspects of groundnut nutrition are limited particularly under varied soil moisture regimes, hence efforts are needed to quantify the crop response *vis-a-vis* at different nutrient levels.

Sulphur is essential to plant nutrition, and the fourth major plant nutrient next to nitrogen (N), phosphorus (P) and potassium (K) especially for oilseed crops. It is essential for synthesis of oil, in addition to protein production and activation of enzymes. It is a constituent of the aminoacids like cysteine, cystine and methionine and also involved in the formation of glucosides or glucosinolates, which on hydrolysis increase the oil content. It also plays an important role in chlorophyll and vitamin formation [2].

Calcium is required by groundnut plants from the time when pegs begins to appear fruit formation, until the pods are mature. Calcium deficiency leads to high percentage of aborted seeds (empty pods), improperly filled pods [3].

Gypsum is a moderately soluble source of the essential plant nutrients *viz*., calcium and sulphur, and improve overall plant growth. Gypsum amendments can also improves soil physical properties, prevents crust formation, promote seedling emergence, increase water infiltration rates and movement through the soil profile.

Keeping these points in view, an experiment was designed in groundnut to study the effect of growth and yield of *rabi* groundnut for a profitable approach to realize the maximum yield potential.

2. Materials and Methods

The experiment was conducted during *rabi* season 2021at Krishi vignan Kendra, Palem, Nagarkurnool, India. The present research work is framed with an objective to study the effect of moisture regimes and gypsum levels on growth and yield of *rabi* groundnut. The experiment was laid out in split plot design. The soil was sandy loam in texture with pH of 7.1, medium in available nitrogen, phosphorus and potassium. The experiment consisted of 15 treatment combinations *viz.,* three moisture regimes (0.6IW/CPE, 0.8 IW/CPE and 1.0 IW/CPE), and five gypsum levels (G_0- control, G_1- 300 kg ha^{-1}, G_2- 400 kg ha^{-1},G_3- 500 kg ha^{-1} and G_4- 600 kg ha^{-1}) applied as basal at peg formation stage. Fertilizers urea and diaminophosphate (DAP) (for N and P), potassium chloride (MOP) for K_2O were applied to supply 30 kg N, 40 kg P_2O_5 and 50 kg $ha^{-1}$$K_2O$. Entire phosphorus and potash, half of the nitrogen (urea) were uniformly broadcasted before sowing and incorporated into the soil. Remaining half dose of nitrogen was top-dressed by band placement between 25-30 days after sowing depending on irrigation dates as per schedule of treatments. Crop was sown at a row distance of 30cm and plant to plant of 10cm. The crop was sown during 4th week of December and harvested at 4th week of April. Five plants were randomly selected in each net plot area for taking observations on growth and yield attributing parameters. The samples were first dried under shade and then in electric oven at temperature of 60°C till attaining constant weight, on the basis of weight of these samples, then converted into dry matter production (kg ha^{-1}).Data of growth attributes that is plant height (cm), number of branches per plant, leaf area (cm^2 $plant^{-1}$), dry matter production (kg ha^{-1}). Data obtained were statistically analyzed as suggested by [4].

There is little information about the soils other than sandy texture and neutral pH. Are they low in sulphur, which required the gypsum amendments, or are groundnuts a high sulfur consumer?

To clarify especially that sulfur is less important than nitrogen, phosphorus and potassium which are major elements for almost all cultivated plants.

3. Results and discussion

3.1 Growth parameters

3.1.1 Moisture regimes

The plant height varied among different moisture regimes. At before gypsum application stage, the plant height showed non-significant with different moisture regimes. Higher values of plant height at 60, 90 DAS and at harvest (20.20, 23.99 and 27.87 cm) was recorded with I_3 (1.0 IW/CPE) which was significantly higher and on par with the treatment I_2 (0.8 IW/CPE) (18.16, 23.60 and 26.69 cm), this was due to availability of more number of irrigations which favored the plant height. The results are in line with Pawar *et al*. [5].

Higher number of branches plant^{-1} (13.07 and 14.20) were recorded at 60 and 90 DAS with I_3 (1.0 IW/CPE) which was on par (12.42 and 13.17) with I_2 (0.8 IW/CPE) followed by I_1 (0.6 IW/CPE), whereas at before gypsum application plant height found to be non-significant. This is due to availability of more moisture at root zone depth due to frequent irrigations. These results were similar with Desai *et al*. [6].

Leaf area (934.86, 706.93 and 174.06 cm^2 plant^{-1}) at 60, 90 DAS and at harvest which was significantly higher with I_3 (1.0IW/CPE) over other treatments except at harvest which is on par with I_2 (0.8 IW/CPE), dry matter plant^{-1} (1113.76, 1996.78 and 2711.67 kg ha^{-1}) at 60, 90 DAS and at harvest was significantly higher with I_3 (1.0 IW/CPE) which is on par with I_2 (0.8 IW/CPE) at 90 DAS and at harvest. Whereas, before gypsum application stage was found to be non-significant. Frequent irrigations provide more moisture, more nutrients to the crop and production of more biomass through the process of plant metabolism produced more leaf area. Thesefindings were in close confirmity with Laxmi [7] and with Karuna sagar and Narsareddy [8].Put the names of the authors only and not the first names.

3.1.2 Gypsum levels

Among the gypsum levels, G_4at 600 kg ha^{-1} showed significantly higher values of plant height (20.84,25.48 and 28.93 cm) which was on par with G_3at 500 kg ha^{-1} (19.35, 24.74 and 28.07 cm) compared to other treatments. The increase in plant height might be attributed due to which might be due to the availability of calcium and sulphur through gypsum might have favoured for put forth and more plant height.Results were similar withPasalaramya& Rajesh singh [9] and Kannan [10].Put the names of the authors only and not the first names.

Branches plant^{-1}at before gypsum application was found to be non-significant with varied gypsum levels. At 60 and 90DAS, branches plant^{-1} showed significantly higher values (13.80 and 15.85) with G_4at 600 kg ha^{-1} which is on par (13.36) with G_3at 500 kg ha^{-1} at 60DAS. These findings were similar with findings of Rao &Shakawat [11].

Higher values of leaf area (cm^2 plant^{-1}) (1351.3, 843.6 and 194.6 cm^2 plant^{-1}) at 60, 90 DAS and at harvest respectively,were observed with G_4at 600 kg ha^{-1} which is significantly higher compared to other treatments. Dry matter accumulation (kg ha^{-1}) (1566.7, 2201.5 and 3038.2 kg ha^{-1}) showed significantly higher values with (G_4at 600 kg ha^{-1}) compared to other treatments, while lowest values recorded with (G_0- control) (650.4, 1770.5 and 2375.0 kg ha^{-1}). Similar results were documented byLongkumer&Gohain [14].

The leaf area (cm^2 plant^{-1}) interaction at 60 DAS with moisture regimes and gypsum levels at I_3G_4 (1.0 IW/CPE) and (G_4at 600 kg ha^{-1}) showed significantly higher value (1456.0 cm^2 plant^{-1}) whereas lowest leaf area (463.0 cm^2 $plant^{-1}$) recorded with I_1G_0 (0.6 IW/CPE) and (G_0- control). These findings were similar with findings of Naresha*et al*. [15].

3.2 Yield attributes

3.2.1 Moisture Regimes

Pod yield and halum yield (kg ha^{-1}) (2337.6 and 1659.0 kg ha^{-1}) are significantly higher with I_3 (1.0IW/CPE) followed by I_2 (0.8 IW/CPE) (2254.0 and 1465.8 kg ha^{-1}) while least value (2113.6 and 1309.4 kg ha^{-1}) with I_1 (0.6 IW/CPE). Pod yield increase is due to increase in irrigation which ascribed to adequate moisture availability in turns have favored congenial conditions for the luxurious growth of crop and consequently increased the values of the yield attributes with I_3 compared to I_2 and I_1 treatments. These findings were in close confirmity with Naresha*et al*. [15], Dash *et al.*[16] and Kumaran*et al*. [17].Not cited in the list

3.2.2 Gypsum levels

Among varied levels of gypsum, G_4at 600 kg ha^{-1} showed significantly higher values (2829.7 and 1752.2 kg ha^{-1}) of pod and halum yield (kg ha^{-1}) compared to other treatments. Least value of pod and halum yield (1815.6 and 1070.0 kg ha^{-1}) with G_0- control. Gypsum application might have ensured adequate supply of calcium and sulphur, have favored not only in pod formation but also in better filling of the pods thus would have increased number of filled pods(Salke*et al*.) [18].Not cited in the list

Data regarding interaction between moisture regimes and gypsum levels on pod yieldand haulm yield (kg ha^{-1}) showed that significantly higher values with I_3G_4 (1.0 IW/CPE and G_4at 600 kg ha^{-1}) (3056.4 kg ha^{-1}) and compared to other treatments, while least value (1717.8 kg ha^{-1}) with I_1G_0(0.6 IW/CPE and G_0-control). Higher amount of gypsum level increased the calcium and sulphur levels have favored not only pod formation but also in better filling of the pods and more irrigations favored the pod yield in groundnut. These findings were similar with Naresh *et al.*[15].

4. CONCLUSION

This field experiment inferred that moisture regime I_3 (1.0IW/CPE) and Gypsum level (G_4at 600 kg ha^{-1}) showed highest values of growth parameters and yield attributes which can be cultivated for realizing higher pod yield under *rabi* conditions on sandy loam soils of Telangana region.

The conclusion shows that the best yields are obtained with the maximum irrigation water and the maximum dose of gypsum. This generates a high-water consumption firstly and probably an excess deposit of gypsum in the soil after several years of amendment secodly. Indeed, 600 kg of gypsum ($CaSO_4.2H_2O$) provide the soil with 148 kg of calcium and 118 kg of sulphur. Do groundnuts really need all these quantities to achieve the best yields? We must bear in mind that sustainable production must preserve natural resources by avoiding their waste and also their pollution.

Table 1: Plant height (cm) of *rabi* groundnut as influenced by moisture regimes andgypsum levels at different crop growth stages

Treatments	Plant height (cm)			
	Before gypsum	60 DAS	90 DAS	At harvest
MOISTURE REGIMES (I)				
I_1- 0.6 IW/CPE	12.07	16.74	23.20	24.36
I_2- 0.8 IW/CPE	12.78	18.16	23.60	26.69
I_3- 1.0 IW/CPE	13.16	20.20	23.99	27.87
SEm ±	0.47	0.54	0.04	0.55
CD (P=0.05)	NS	2.20	0.19	2.24
GYPSUM LEVELS (GP)				
G_0- Control	12.01	16.01	21.44	23.53
G_1- Gypsum @ 300 kg ha^{-1}	12.48	17.26	22.59	24.34
G_2- Gypsum @ 400 kg ha^{-1}	12.33	18.36	23.73	26.66
G_3- Gypsum @ 500 kg ha^{-1}	13.27	19.35	24.73	28.07
G_4- Gypsum @ 600 kg ha^{-1}	13.24	20.84	25.48	28.93
SEm±	0.34	0.61	0.17	0.81
CD (P=0.05)	NS	1.80	0.51	2.38
INTERACTION (I X GP)				
Sub treatment at same level of main treatment				
SEm±	1.06	1.22	0.10	1.24
CD (P= 0.05)	NS	NS	NS	NS
Main treatment at same or different level of sub treatment				
SEm±	0.71	1.09	0.27	1.37
CD (P=0.05)	NS	NS	NS	NS

Do the numbers correspond to averages? Where are the standard deviations then?

Meaning of the abbreviations CD and SEM?To be placed below the table.

Table 2: Number of branches $plant^{-1}$ of *rabi* groundnut as influenced by moisture regimes and gypsum levels at different crop growth stages

Treatments	Number of branches $plant^{-1}$		
	Before gypsum	60 DAS	90 DAS

MOISTURE REGIMES (I)			
I_1- 0.6 IW/CPE	6.90	11.36	12.19
I_2- 0.8 IW/CPE	7.13	12.42	13.17
I_3- 1.0 IW/CPE	7.24	13.07	14.20
SEm ±	0.32	0.18	0.35
CD (P=0.05)	NS	0.73	1.41
GYPSUM LEVELS (GP)			
G_0- Control	6.37	10.83	11.22
G_1- Gypsum @ 300 kg ha^{-1}	6.92	11.22	11.81
G_2- Gypsum @ 400 kg ha^{-1}	6.87	12.20	12.37
G_3- Gypsum @ 500 kg ha^{-1}	7.42	13.36	14.67
G_4- Gypsum @ 600 kg ha^{-1}	7.86	13.80	15.85
SEm±	0.37	0.29	0.39
CD (P=0.05)	NS	0.87	1.15
INTERACTION (I X GP)			
Sub treatment at same level of main treatment			
SEm±	0.72	0.40	0.78
CD (P= 0.05)	NS	NS	NS
Main treatment at same or different level of sub treatment			
SEm±	0.65	0.49	0.70
CD (P=0.05)	NS	NS	NS

Table 3: Leaf area (cm^2 plant^{-1})of *rabi* groundnut as influenced by moisture regimes andgypsum levels at different crop growth stages

Treatments	Leaf area cm^2 plant^{-1}			
	Before gypsum	60 DAS	90 DAS	At harvest
MOISTURE REGIMES (I)				
I_1- 0.6 IW/CPE	432.40	777.06	650.60	165.20
I_2- 0.8 IW/CPE	433.80	852.06	682.33	170.40
I_3- 1.0 IW/CPE	434.20	934.86	706.93	174.06
SEm ±	4.03	4.25	3.98	1.18
CD (P=0.05)	NS	17.16	16.06	4.79
GYPSUM LEVELS (GP)				
G_0- Control	425.88	485.00	525.00	146.66
G_1- Gypsum @ 300 kg ha^{-1}	429.22	624.11	603.88	156.66
G_2- Gypsum @ 400 kg ha^{-1}	435.22	799.33	672.44	168.00
G_3- Gypsum @ 500 kg ha^{-1}	437.55	1013.55	754.77	183.44
G_4- Gypsum @ 600 kg ha^{-1}	439.44	1351.33	843.66	194.66

SEm±	3.74	8.44	5.99	1.20
CD (P=0.05)	NS	24.79	17.60	3.53
INTERACTION (I X GP)				
Sub treatment at same level of main treatment				
SEm±	9.02	9.52	8.91	2.66
CD (P= 0.05)	NS	44.47	NS	NS
Main treatment at same or different level of sub treatment				
SEm±	7.06	13.75	10.10	2.21
CD (P=0.05)	NS	41.83	NS	NS

Table 4:Drymatter production (kg ha^{-1})of *rabi* groundnut as influenced by moisture regimes and gypsum levels at different crop growth stages

Treatments	Drymatter production (kg ha^{-1})			
	Before gypsum	60 DAS	90 DAS	At harvest
MOISTURE REGIMES (I)				
I_1- 0.6 IW/CPE	442.45	946.82	1933.84	2618.42
I_2- 0.8 IW/CPE	442.52	1017.67	1973.47	2663.44
I_3- 1.0 IW/CPE	443.04	1113.76	1996.78	2711.67
SEm ±	2.48	10.48	7.29	13.91
CD (P=0.05)	NS	41.26	29.39	56.11
GYPSUM LEVELS (GP)				
G_0- Control	442.11	650.48	1770.56	2375.07
G_1- Gypsum @ 300 kg ha^{-1}	442.26	812.96	1870.45	2538.41
G_2- Gypsum @ 400 kg ha^{-1}	442.43	929.59	1941.89	2622.37
G_3- Gypsum @ 500 kg ha^{-1}	442.67	1170.59	2055.67	2748.49
G_4- Gypsum @ 600 kg ha^{-1}	443.89	1566.78	2201.59	3038.22
SEm±	3.73	10.71	18.34	21.91
CD (P=0.05)	NS	31.45	53.86	64.34
INTERACTION (I X GP)				
Sub treatment at same level of main treatment				
SEm±	5.54	23.43	16.30	31.12
CD (P= 0.05)	NS	60.28	NS	NS
Main treatment at same or different level of sub treatment				
SEm±	6.29	19.63	29.33	36.69
CD (P=0.05)	NS	63.77	NS	NS

Table 4a: Dry matter production (kg ha^{-1}) of *rabi* groundnut at 60 DAS as influenced by interaction between moisture regimes and gypsum levels

GYPSUM LEVELS	MOISTURE REGIMES (I)			
	I_1- 0.6 IW/CPE	I_2- 0.8 IW/CPE	I_3-1.0 IW/CPE	MEAN
G_0- Control	590.2	650.6	710.5	650.4
G_1- Gypsum @ 300 kg ha^{-1}	775.7	812.5	850.5	812.9
G_2- Gypsum @ 400 kg ha^{-1}	890.6	901.4	996.6	929.5
G_3- Gypsum @ 500 kg ha^{-1}	1201.0	1145.2	1345.5	1170.5
G_4- Gypsum @ 600 kg ha^{-1}	1456.4	1578.4	1665.4	1566.7
MEAN	946.8	1017.6	1113.7	
Sub treatment at same level of main treatment				
SEm±				23.4
CD (P=0.05)				60.2
Main treatment at same or different level of sub treatment				
SEm±				19.6
CD (P=0.05)				63.7

Table 5: Yield attributes of *rabi* groundnut as influenced by moisture regims andgypsum levels at different crop growth stages

Treatments	Yield	
	Pod yield (kg ha^{-1})	Halum yield (kg ha^{-1})
MOISTURE REGIMES (I)		
I_1- 0.6 IW/CPE	2113.60	1309.40
I_2- 0.8 IW/CPE	2254.00	1465.86
I_3- 1.0 IW/CPE	2337.68	1659.06
SEm ±	11.01	9.18
CD (P=0.05)	44.39	37.02
GYPSUM LEVELS (GP)		
G_0- Control	1815.62	1070.00
G_1- Gypsum @ 300 kg ha^{-1}	1964.53	1410.00
G_2- Gypsum @ 400 kg ha^{-1}	2145.76	1532.22
G_3- Gypsum @ 500 kg ha^{-1}	2419.73	1626.11

G_4- Gypsum @ 600 kg ha^{-1}	2829.78	1752.22
SEm±	22.28	10.299
CD (P=0.05)	65.43	30.24
INTERACTION (I X GP)		
Sub treatment at same level of main treatment		
SEm±	24.62	20.53
CD (P= 0.05)	117.24	57.24
Main treatment at same or different level of sub treatment		
SEm±	36.23	18.41
CD (P=0.05)	110.07	59.07

Table 5.a: Pod yield (kg ha^{-1}) of *rabi* groundnut as influenced by interaction between moisture regimes and gypsum levels

GYPSUM LEVELS	MOISTURE REGIMES (I)			
	I_1- 0.6 IW/CPE	I_2- 0.8 IW/CPE	I_3-1.0 IW/CPE	MEAN
G_0- Control	1717.8	1834.5	1894.4	1815.6
G_1- Gypsum @ 300 kg ha^{-1}	1902.3	1967.4	2023.7	1964.5
G_2- Gypsum @ 400 kg ha^{-1}	2023.5	2167.9	2245.7	2145.7
G_3- Gypsum @ 500 kg ha^{-1}	2356.7	2434.5	2467.9	2419.7
G_4- Gypsum @ 600 kg ha^{-1}	2567.4	2865.4	3056.4	2829.7
MEAN	2113.6	2254.0	2337.6	
Sub treatment at same level of main treatment				
SEm±				24.6
CD (P=0.05)				117.2
Main treatment at same or different level of sub treatment				
SEm±				36.2
CD (P=0.05)				110.0

Table 5b: Haulm yield (kg ha^{-1}) of *rabi* groundnut as influenced by interaction between moisture regimes and gypsum levels

GYPSUM LEVELS	MOISTURE REGIMES (I)			
	I_1- 0.6 IW/CPE	I_2- 0.8 IW/CPE	I_3-1.0 IW/CPE	MEAN
G_0- Control	1011.3	1098.0	1100.6	1070.0
G_1- Gypsum @ 300 kg ha^{-1}	1234.0	1398.0	1598.0	1410.0
G_2- Gypsum @ 400 kg ha^{-1}	1301.0	1498.0	1797.6	1532.2
G_3- Gypsum @ 500 kg ha^{-1}	1434.0	1601.3	1843.0	1626.1
G_4- Gypsum @ 600 kg ha^{-1}	1566.6	1734.0	1956.0	1752.2
MEAN	1309.4	1465.8	1659.0	
Sub treatment at same level of main treatment				
SEm±				20.5
CD (P=0.05)				57.2
Main treatment at same or different level of sub treatment				
SEm±				18.4
CD (P=0.05)				59.0

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