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Effect of levels of gypsum and phosphogypsum application on yield contributing characters of summer groundnut grown on Inceptisol

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Abstract
The present investigation was conducted during 2017-18, 2018-19 on Inceptisol with a view to study the "Effect of graded levels of gypsum and phosphogypsum application yield contributing characters of summer groundnut" at Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). The experiment was laid out in randomized block design with three replications and nine treatments. There were nine treatments including absolute control, RDF (DAP, urea, MOP) sulphur free, RDF through urea, SSP, MOP, RDF-sulphur free with soil application of gypsum @ 200, 300 and 400 kg ha^{-1} and RDF-sulphur free with soil application of phosphogypsum @ 200, 300 and 400 kg ha^{-1} Five plants each of groundnut were selected randomly and tagged in each plot for recording various post-harvest observations. The present study reported that the number of filled pods per plant were significantly higher in RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1}. The yield contributing characters such as hundred pod weight, hundred kernel weight and shelling percentage of groundnut was found significantly higher in RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1}.

Keywords: Inceptisol, groundnut, yield attributing characters, gypsum and phosphogypsum

Introduction
Asia has the largest area of groundnut cultivation in the world contributing to 67 per cent of the total production in 2016. India holds the largest acreage (6.7 million ha) followed by China (4.7 million ha), Indonesia, Myanmar, Pakistan and Thailand. There has been an important increase in harvested area in Asia in the last two decades, mainly in China, Hong Kong, Japan, Korea and Taiwan. More than 25 per cent of the groundnut area harvested in the world is in India followed by 20 per cent in China. However, China is the largest producer of groundnut and accounts for 37 per cent of world production, followed by India with 22 per cent. The average productivity of groundnut in Asia is 1739 kg ha^{-1}. In India the important groundnut growing states are Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, and Rajasthan. The crop is grown in all three seasons: rainy, post-rainy, and during summer months. It is mostly cultivated under rain fed conditions; only about 10-15% of the cropping area is irrigated.

Considering the oilseeds scenario of Maharashtra state during 2015-16, groundnut contributed 28.6 per cent area and added 47.26 per cent to total production, with highest productivity (1198.5 kg ha^{-1}). Major groundnut growing districts in Maharashtra are Dhule, Satara, Kolhapur, Pune, Nasik, Ahmednagar, Parbhani and Jalgaon. Maharashtra recorded 7.16 and 2.15 lakh hectares area under groundnut with production of 6.20 and 2.45 lakh metric tonnes during kharif and summer seasons during 2016-17, respectively. The productivity of kharif and summer groundnut in Maharashtra was higher i.e. 1018 and 1271 kg ha^{-1}, respectively during 2016-17 (Anonymous, 2016) [1].

The low groundnut productivity of Indian soils could be attributed to several production constraints, which include poor and imbalanced nutrition of crop and growing crop on marginal lands. Therefore, it is most essential to pay greater attention to the nutrition of the groundnut to enhance its productivity. Calcium and sulphur are recognized as fourth and fifth major essential plant nutrients, respectively, for growth and development of plants. Most of the Vertisols in Vidarbha are now days found deficit in calcium, sulphur, phosphorus and zinc (Meena *et al.*, 2007) [7]. These nutrients play an important role in the plant metabolisms and physiology of all oilseed crops. So, individual application of these nutrient sources increases the input cost on fertilizer application. Hence, it is pertinent to evaluate the influence of combined source (gypsum and phosphogypsum) which costs lower in comparison to individual application of fertilizer nutrients.

Calcium and sulphur requirements of groundnut are quite heavy. In neutral and alkaline soils of sandy texture calcium deficiency may become serious. Previously, no special efforts were made to supplement these nutrients to soils, since, these nutrients got added inadvertently through SSP as a byproduct with 11 per cent S and 18 per cent Ca in the form of Calcium sulphate i.e. gypsum. Hence, here by reviewing the literatures, technical sources and constant consultations with the farming community, it was decided to identify the cheap and combined source of essential nutrients and other secondary nutrients and micronutrients for the oil seed crop. In view of above, a field experiment was conducted to study the "Effect of Calcium and Sulphur Application on agronomic characters and Quality of Summer Groundnut".

Material and Methods

A field experiment was conducted at Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2017-18 and 2018-19. Experimental field is situated at the latitude of 22^{0}42' 19.2" North and 77^{0} 03' 43.2" East at the altitude of 307.8 (m) above mean sea level (MSL). Average annual precipitation is 711.1 mm. Most of the rainfall is received from south west monsoon. The texture of soil was clay loam with pH 7.7, EC 0.2 dSm^{-1}, organic carbon 5.6 g kg^{-1}, available N 181 kg ha^{-1}, available P 17 kg ha^{-1}, available K 332 kg ha^{-1}, available sulphur 10 mg kg^{-1}. The experiment was carried out using randomized block design with three replications and nine treatments. The details of the treatments were T1 control, T2 recommended dose of fertilizer (RDF) (DAP, urea and MOP) sulphur free, T3 RDF through urea, SSP, MOP, T4 RDF sulfur free + 200 kg gypsum ha^{-1}, T5 RDF sulfur free + 300 kg gypsum ha^{-1}, T6 RDF sulfur free + 400 kg gypsum ha^{-1}, T7 RDF sulfur free + 200 kg phosphogypsum ha^{-1}, T8 RDF S free + 300 kg phosphogypsum ha^{-1}, T9 RDF S free + 400 kg phosphogypsum ha^{-1}). Soil application of gypsum and phosphogypsum was done at 45 days after sowing. Recommended dose of 25:50:30 kg N, P_2O_5 and K_2O was applied as urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively. On an average, gypsum and phosphogypsum contained 23, 18.5 and 22, 15.5% calcium and sulfur, respectively. Tag 24 variety of groundnut was sown in rows, 20 cm apart using 100 kg seeds ha^{-1} in the first week of February during both the years. Crop was harvested during last week of May in both the years at physiological maturity and yield were recorded.

Observations and recording of yield contributing characters: Five plants each of groundnut were selected randomly and tagged in each plot for recording various post-harvest observations (Number of filled pods per plant, Number of unfilled pods per plant, Number of single kernel pods per plant, Number of double Kernal pods per plant, Number of triple kernel pods per plant. After complete development of pods, plants were uprooted from the net plot area. The pods were separated from the rest of the plant parts and then dried under shade.

Hundred pod weight (g)

Number of pods per five plant yield was counted and their weight was recorded in grams. Then it was adjusted to hundred pod weight as.

100 pod weight = Weight of pod × 100 number of pod

Hundred kernel weight (g)

Number of kernel per five plant yield was counted and their weight was recorded in grams. Then it was adjusted to hundred kernel weight as.

100 kernel weight = Weight of kernels × 100 number of kernel

Shelling (%)

A representative sample of 100 gram dry pods from each treatment was shelled to obtain the kernel weight. Then shelling percentage was worked out as follows.

$$\text{Shelling per cent} = \frac{\text{Kernel weight}}{\text{Dry pod weight}} \times 100$$

Pod yield (kg ha^{-1})

The pods were separated manually from the plants of each net plot. The weight was recorded separately for each net plot and converted on hectare basis.

Haulm yield (kg ha^{-1})

The plot wise haulm yield per net plot was obtained by deducting the pod yield from the total produce (biological yield) and recorded in kg per net plot later on it was converted on hectare basis.

Statistical analysis and interpretation of data

The test of statistically significance to the experimental data was carried out as per procedure described by Gomez and Gomez (1983) [3]. The data of soil and plant was calculated for each parameter and interpreted.

Result and Discussion

Pod filling (number of filled and unfilled pods) at harvest of groundnut

The number of filled and unfilled pods at harvest of groundnut was significantly influenced by levels of gypsum and phosphogypsum during 2017-18, 2018-19 and pooled mean (Table 1). RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1} recorded significantly higher filled pods per plant in 2017-18, 2018-19 and pooled mean (13.80, 16.80, 15.30, respectively). However, it was statistically on par with RDF-sulphur free with soil application of gypsum @ 400 kg ha^{-1}. RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1} recorded significantly lower unfilled pods per plant in 2017-18, 2018-19 and pooled mean (2.00, 1.80 and 1.93 respectively). However, it was statistically on par with RDF-sulphur free with soil application of gypsum @ 400 kg ha^{-1} in 2017-18 and RDF-sulphur free with soil application of gypsum @ 400 kg ha^{-1}, RDF-sulphur free with soil application or phosphogypsum @ 300 kg ha^{-1} in 2018-19. These results are in conformity with Naresha *et al.* (2014) [4] and Meena *et al.* (2007) [7].

Single, double, and triple kernel in pods per plant at harvest of groundnut

The number of single, double and triple kernel in pods per plant at harvest of groundnut was significantly influenced by levels of gypsum and phosphogypsum during 2017-18, 2018-19 and pooled mean (Table 2). RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1} recorded significantly higher kernels (Single, double, triple) in pods per plant in 2017-18, 2018-19 and pooled mean (4.60, 6.00 and 5.30 respectively). However, it was statistically on par with RDF-sulphur free with soil application of gypsum @ 400 kg ha^{-1} in 2017-18, and RDF-sulphur free with soil application of gypsum @ 400 kg ha^{-1}, RDF-sulphur free with soil application of phosphogypsum @ 300 kg ha^{-1} in 2018-19 and pooled mean. These results are in agreement with Naresha *et al.* (2014) [4], Meena *et al.* (2007) [7], Rao and Shaktawat (2002).

Yield contributing characters of groundnut grown on Inceptisol

The hundred pod weight, hundred kernel weight and shelling percentage was significantly influenced by levels of gypsum and phosphogypsum during 2017-18, 2018-19 and pooled mean (Table 3). RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1} recorded significantly higher hundred pod weight, hundred kernel weight, shelling percentage in 2017-18, 2018-19 and pooled mean. However, it was statistically on par with RDF-sulphur free with soil application of gypsum @ 400 kg ha^{-1} in pooled mean. These results are in agreement with Meena *et al.* (2007) [7], Sahu *et al.* (2001) [6] and Naresha *et al.* (2014) [4].

Table 1: Effect of graded levels of gypsum and phosphogypsum on number of filled and unfilled pods at harvest of groundnut grown on Inceptisol

Treatment		Number pods per plant					
		Number of filled			Number of unfilled		
		2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1:	Absolute control	4.60	6.60	5.60	6.80	7.60	7.08
T_2:	RDF (DAP, urea and MOP) sulphur free	6.60	8.40	7.50	5.20	4.80	5.06
T_3:	RDF through urea, SSP, MOP	7.00	9.40	8.20	5.00	4.00	4.65
T_4:	T_2 + Soil application of Gypsum @ 200 kg ha^{-1}	10.00	11.00	10.50	4.20	3.60	3.99
T_5:	T_2 + Soil application of Gypsum @ 300 kg ha^{-1}	11.60	13.40	12.50	3.80	2.80	3.45
T_6:	T_2 + Soil application of Gypsum @ 400 kg ha^{-1}	13.40	16.20	14.80	2.20	2.00	2.13
T_7:	T_2 + Soil application of Phosphogypsum @ 200 kg ha^{-1}	8.80	11.80	10.30	4.00	3.20	3.72
T_8:	T_2 + Soil application of Phosphogypsum @ 300 kg ha^{-1}	12.00	15.00	13.50	3.20	2.40	2.92
T_9:	T_2 + Soil application of Phosphogypsum @ 400 kg ha^{-1}	13.80	16.80	15.30	2.00	1.80	1.93
	SE (m) +	0.25	0.55	0.35	0.21	0.28	0.27
	CD at 5%	0.75	1.66	1.15	0.62	0.85	0.88

Table 2: Effect of graded levels of gypsum and phosphogypsum on single, double and triple kernel in pods per plant at harvest of groundnut grown on Inceptisol

Treatment		Number pods per plant								
		Number of single kernel			Number of double kernel			Number of triple kernel		
		2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1:	Absolute control	0.80	2.00	1.40	3.40	4.20	3.80	0.40	0.40	0.40
T_2:	RDF (DAP, urea and MOP) sulphur free	1.40	3.00	2.20	4.40	4.80	4.60	0.80	0.60	0.70
T_3:	RDF through urea, SSP, MOP	1.60	3.40	2.50	4.60	5.40	5.00	0.80	0.60	0.70
T_4:	T_2 + Soil application of Gypsum @ 200 kg ha^{-1}	3.60	4.00	3.80	5.20	5.80	5.50	1.20	1.20	1.20
T_5:	T_2 + Soil application of Gypsum @ 300 kg ha^{-1}	3.40	4.80	4.10	6.80	6.80	6.80	1.40	1.80	1.60
T_6:	T_2 + Soil application of Gypsum @ 400 kg ha^{-1}	4.40	5.80	5.10	7.40	8.00	7.70	1.60	2.40	1.99
T_7:	T_2 + Soil application of Phosphogypsum @ 200 kg ha^{-1}	2.20	4.40	3.30	5.40	6.20	5.80	1.20	1.20	1.20
T_8:	T_2 + Soil application of Phosphogypsum @ 300 kg ha^{-1}	3.80	5.40	4.60	6.80	7.40	7.10	1.40	2.20	1.79
T_9:	T_2 + Soil application of Phosphogypsum @ 400 kg ha^{-1}	4.60	6.00	5.30	7.60	8.40	8.00	1.60	2.40	1.99
	SE (m) +	0.16	0.26	0.24	0.21	0.46	0.13	0.11	0.11	0.22
	CD at 5%	0.49	0.79	0.80	0.64	1.38	0.43	0.32	0.33	0.71

Table 3: Effect of graded levels of gypsum and phosphogypsum on yield contributing characters of groundnut grown on Inceptisol

Treatment		Yield contributing characters								
		Hundred pod weight (g)			Hundred kernel weight (g)			Shelling percentage (%)		
		2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1:	Absolute control	69.60	69.20	69.39	39.92	39.70	39.81	67.87	67.10	67.86
T_2:	RDF (DAP, urea and MOP) sulphur free	69.98	70.08	70.03	40.07	40.22	40.15	68.03	68.92	68.04
T_3:	RDF through urea, SSP, MOP	70.32	70.48	70.40	40.28	40.56	40.42	68.41	69.33	68.42
T_4:	T_2 + Soil application of Gypsum @ 200 kg ha^{-1}	71.28	71.99	71.65	40.79	41.24	41.01	68.79	69.74	68.80
T_5:	T_2 + Soil application of Gypsum @ 300 kg ha^{-1}	71.89	72.94	72.44	41.83	41.98	41.91	69.43	70.37	69.44
T_6:	T_2 + Soil application of Gypsum @ 400 kg ha^{-1}	72.67	73.44	73.07	42.67	42.74	42.71	70.11	71.07	70.12
T_7:	T_2 + Soil application of Phosphogypsum @ 200 kg ha^{-1}	71.30	72.06	71.70	41.21	41.32	41.27	69.03	69.98	69.04
T_8:	T_2 + Soil application of Phosphogypsum @ 300 kg ha^{-1}	72.23	73.12	72.70	42.11	42.28	42.20	69.78	70.70	69.79
T_9:	T_2 + Soil application of Phosphogypsum @ 400 kg ha^{-1}	73.08	73.86	73.49	43.21	43.33	43.27	70.69	71.59	70.70
	SE (m) +	0.10	0.09	0.24	0.04	0.14	0.09	0.02	0.18	0.06
	CD at 5%	0.29	0.27	0.77	0.12	0.41	0.29	0.06	0.53	0.19

Pod and haulm yield of groundnut grown on Inceptisol

The pod and haulm yield of groundnut was significantly influenced by the levels of gypsum and phosphogypsum during 2017-18, 2018-19 and pooled mean (Table 4). The soil application of phosphogypsum @ 400 kg ha^{-1} along with RDF (DAP, urea and MOP) sulphur free recorded significantly higher pod yield of groundnut during 2017-18 2018-19 and pooled mean (2036.00, 2138.00 and 2087.00 kg ha^{-1} respectively). However, it was statistically on par with all the treatments during 2017-18 except absolute control, RDF-sulphur free and RDF and during 2018-19 except absolute control, RDF-sulphur free. In case of pooled mean it was statistically on par with all the treatments except absolute control, RDF-sulphur free, RDF and RDF-sulphur free with soil application of gypsum @ 200 kg ha^{-1} The results revealed that the soil application of gypsum and phosphogypsum @ 200, 300 kg ha^{-1} along with RDF (DAP urea and MOP) sulphur free are equally beneficial for pod yield a groundnut. Therefore, the lower doses of gypsum and phosphogypsum are also useful for harvesting good economical yield of groundnut. The pod yield of groundnut was numerically the highest in treatment RDF (DAP, Urea and MOP) sulphur free with phosphogypsum @ 400 kg ha^{-1} during 2017-18, 2018-19 and pooled mean (2036.00, 2138.00 and 2087.00 kg ha^{-1} respectively) and closely followed by RDF (DAP, urea and mop) sulphur free with gypsum @ 400 kg ha^{-1} (1998.00, 2056.00 and 2027.00 kg ha^{-1}, respectively). This might be associated with both gypsum and phosphogypsum contains sufficient amount of calcium, which require in groundnut for proper shell formation, calcium also improves the workability of soil by which there might be easy to penetration of pegs into soil forms the more number of pods. The added calcium might be maintained the Ca: B ratio in soil for proper growth and development of groundnut flower induction, peg formation, pollen viability etc. and ultimately reflected in higher yield of groundnut. The gypsum and phosphogypsum both are also act as soil amendments and improves the soil physical, chemical and biological condition, this might help to improves the nutrient availability in soil for groundnut for enhancing the pod yield so that both gypsum and phosphogypsum @ 400 kg ha^{-1} along with RDF (DAP, urea and MOP) suphur free numerically increased the yield during both the year and poled mean.

The phosphogypsum is the byproduct of synthesis of single super phosphate which consists of sulphur in addition to calcium and small amount of magnesium. The sulphur and magnesium help to enhance the chlorophyll synthesis in groundnut. The enhanced chlorophyll increased photosynthesis activity in groundnut and assimilate the organic constituents in plant. These organic constituents increased the yield of groundnut. These observations are in conformity of Brigden *et al.* (2002) [2], Naresha *et al.* (2014) [4].

The haulm yield of groundnut as influenced by RDF (DAP, urea, MOP) sulphur free, RDF (urea, SSP and MOP) and levels of gypsum and phosphogypsum @ 200, 300 and 400 kg ha^{-1} showed the similar trend during 2017-18, 2018-19 and pooled mean as that of in pod yield of groundnut.

Table 4: Effect of graded levels of gypsum and phosphogypsum on pod and Haulm yield of groundnut grown on Inceptisol

Treatment		Pod yield (kg ha^{-1})			Haulm yield (kg ha^{-1})		
		2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1:	Absolute control	1350.00	1568.00	1459.00	1452.00	1889.00	1670.50
T_2:	RDF (DAP, urea and MOP) sulphur free	1539.33	1830.00	1684.67	1803.67	2380.00	2091.83
T_3:	RDF through urea, SSP, MOP	1597.67	1880.00	1738.83	2110.67	2430.00	2270.33
T_4:	T_2 + Soil application of Gypsum @ 200 kg ha^{-1}	1790.33	1951.00	1870.67	2238.33	2501.00	2369.67
T_5:	T_2 + Soil application of Gypsum @ 300 kg ha^{-1}	1881.67	2020.00	1950.83	2297.33	2570.00	2433.67
T_6:	T_2 + Soil application of Gypsum @ 400 kg ha^{-1}	1998.00	2056.00	2027.00	2446.00	2606.00	2526.00
T_7:	T_2 + Soil application of Phosphogypsum @ 200 kg ha^{-1}	1752.00	1940.00	1846.00	2141.00	2490.00	2315.50
T_8:	T_2 + Soil application of Phosphogypsum @ 300 kg ha^{-1}	1979.33	2034.00	2006.67	2421.00	2584.00	2502.50
T_9:	T_2 + Soil application of Phosphogypsum @ 400 kg ha^{-1}	2036.00	2138.00	2087.00	2471.00	2688.00	2579.50
	SE (m) +	135.81	96.00	43.74	127.06	139.49	67.30
	CD at 5%	407.16	287.82	142.63	380.93	418.18	219.48

Conclusion

Number of filled pods per plant were significantly higher in RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1}. The yield contributing characters such as hundred pod weight, hundred kernel weight and shelling percentage of groundnut was found significantly higher in RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1}. Pod yield and haulm yield of groundnut was recorded significantly higher in RDF-sulphur free with soil application of phosphogypsum @ 400 kg ha^{-1}.

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