The Pharma Innovation Journal 2021; 10(10): 813-818

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(10): 813-818

www.thepharmajournal.com
Received: 01-08-2021
Accepted: 03-09-2021

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Impact of gypsum applications on major soil nutrients and quality improvement in groundnut (*Arachis hypogaea* L.) crops under inceptisols

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Abstract
The investigation was carried out on impact of major nutrient and gypsum on soil physico-chemical properties, and results revealed that combined application of NPK @ 25:50:20 kg $ha^{-1}$and T_4G_{400} kg ha^{-1} of gypsum in the soils significantly reduced the various attributes of soil nutrients, and results revealed that gypsum application methods in surface layer observed that NPK content in soils were significantly lower in control plot due to no NPK was applied in these treatments. The oil content in groundnut was found to be significantly lower in control in comparison to other gypsum application methods. Oil content in T_1G_{100}, T_2G_{200} and T_3G_{300}were at par with each other. However, oil content in $T_4G_{400}$was found to be significantly superior with each other. Gypsum application methods, NP and K uptake in groundnut was found to be significantly lower in control in comparison to other gypsum application methods. Groundnut nitrogen uptake inT_2G_{200}, T_3G_{300} and T_4G_{400} were statistically at par with each other. However, groundnut nitrogen uptake in T_1G_{100} was significantly lower than inT_2G_{200}, T_3G_{300} and T_4G_{400}. But P and K uptake in groundnut was statistically similar to each other treatments. Overall, we can conclude that gypsum application under Sodic environment create feasible environments for better nutrient uptake, proper infiltration and aeration, increased N, P and K availability and optimum pH for proper growth and quality of groundnut.

Keywords: gypsum, groundnut, oil content and physico-chemical properties of soil

Introduction
Groundnut (*Arachis hypogaea* L.) is one of the principal oilseed as well as economic crops of the world. It is utilized for human consumption as a vegetable oil and protein, as fodder for livestock and as green manure. With about 26% protein, 48% oil and 3% fiber and high content of calcium, thiamine, and niacin, it has all the potential to be used as an economic food supplement to fight malnutrition. Thus, groundnut is nature's gift to man in general and to children, pregnant or nursing women and the poor in particular (Misra, 2006) [25]. About 80% of total groundnut productions in India are crushed for oil extraction, thus improvement in oil content and quality is of interest to plant breeders and millers. Development of cultivars in groundnut varies with the purpose for which it is put to use (Bandyopadhyay and Desai, 2000) [6]. For example, the most important quality requirements of groundnut as a source of oil are high protein and oil content in seeds. Groundnut is an important food and oilseed crop grown in India across varying agro-climatic environments. It is mostly grown (83% of total groundnut area) under rainfed conditions during the monsoon season (June/July to October/November) and the remaining 17% is grown under irrigated conditions in the post monsoon (October–March) season (Singh *et al*., 2014b) [38]. Globally and in India many biotic and abiotic stresses limit the groundnut productivity. However, heat and drought stress have been observed to be the main factors limiting the yield (Prasad *et al*., 2009a, 2009b) [32, 33]. Temperatures during the crop growing period were already close to or above the upper limit of the optimum temperature range (20–30 °C) required for the crop (Weiss, 2000) [47]. The projected temperature changes for these regions in the coming years will intensify heat and drought stresses in groundnut, further limiting productivity.

Groundnut oil is edible oil and finds extensive use as a cooking medium both as refined oil and vegetable Ghee. Being a legume with root nodules, it can synthesize atmospheric nitrogen and therefore improve soil fertility. It is an important protein supplement in cattle and poultry rations. The haulms (plant stalks) are fed (green, dried or silage) to livestock. Groundnut shell is used as fuel for manufacturing coarse boards, cork substitutes etc (Varghese, 2011) [45]. The optimization of the mineral nutrition is the key to optimize the production of groundnut, as it has very high nutrient requirement and the recently released high yielding groundnut varieties remove still more nutrients from the soil. The world annual groundnuts production is around 35.6 million tons from the 26.4 million ha of production area (FAO, 2007) [12]. In India, about 75% of the groundnut area lies in a low to moderate rainfall zone with a short period of distribution. It has been grown over an area of 5.31 million hectare and producing 6.93 million tons of groundnuts (DOAC, 2012) with productivity of 1305 kg ha^{-1}. Its cultivation is mostly confined to the states of Gujarat, Andhra Pradesh, Maharashtra, Tamil Nadu and Karnataka.

The primary nutrients calcium and sulfur also plays an important role in enhancing production and productivity of groundnut. Sulfur is very crucial for the formation of sulfur containing amino acids and oil synthesis and it is also improves both yield and quality of crops reported by Patel and Patel (1994) [31]. Gypsum is widely used as a source of Ca for groundnut worldwide. Groundnut response to Gypsum as with any other fertilizer depends on the fertility status of the soil. The dissolution of Gypsum is fairly rapid and therefore readily adds Ca to the podding zone. However, the major disadvantage of Gypsum is its vulnerability to leaching especially on light textured soils. Positive responses have been observed on sandy soils with pH less than 5.0 (0.01 M $CaCl_2$). Survey data from the small holder farming sector has shown that the majority of the farmers do not apply Gypsum or any other basal fertilizer to groundnut (Chikowo, 1998) [5]. The use of lime instead of Gypsum can provide not only Ca for the ground crop but also improves the availability of other plant nutrients. Proper incorporation of lime into the soil ensures the availability of Ca & S in the podding zone (Cox *et al*., 1982) [8].

The major soils nutrients as well as secondary nutrients like calcium and sulfur govern the significant improvement in production, productivity and its quality in groundnut. Sulfur is very crucial for the formation of sulfur containing amino acids and oil synthesis and it is also improving both yield and quality of crops (Patel and Patel, 1994) [31].

Application of soil amendments like gypsum behaves superior towards physical and chemical properties and brought significant impact on oil content and their nutrient uptakein groundnut (Mayalagu 1983; More and Nalawade 1993) [24, 26]. Thereby, there is urgent need to impact of major soil nutrients and gypsum on soil properties, oil content in groundnut (*arachis hypogaea* l.) crop under *Inceptisols* with following objectives (1) study the impact on gypsum and NPK on soil properties and oil content of groundnut which would be able to improved significant impact on nutrient content and uptake, and ultimately leads to improve the quality of groundnut.

Materials and Methods

Experimental site characteristics

Location

The field experiment was conducted at the experimental farm of Udai Pratap Autonomous College (UPAC); Varansiis situated in the Middle Gangetic Plain region of Agro-climatic Zone (IV) located at25˚317″ N latitude, 82˚973″E longitude and an altitude of 80.71 meter above mean sea level. The soil of the experimental plot was alluvial deposited by river Ganga predominant of illite, quartz and feldspar mineral. and Randomized Complete Block Design (RCBD) selected for the check the efficacy level with different levels of added gypsum (0, 100, 200, 300 and 400 kg ha^{-1}) with RDF (NPK @ 25:50:20 kg ha^{-1}). NPK and gypsum as selected as treatments at the rate of (0, 100, 200, 300 and 400 kg ha^{-1}) with RDF (NPK @ 25:50:20 kg ha^{-1}). The initial soils samples were randomly collected from five different sites and make the composite samples prior to tillage operation from a depth of 0-15 cm. The post-harvest soil samples were collected by using screw auger from surface layers which was selected from each plot from randomly selected three spots. The size of the soil sample reduces by conning and quartering the composites soil sample after air dry, and its pass through a 2 mm sieve by way of preparing the sample for physical and chemical analysis. The composite soil samples were collected from each plot after field preparation and from each plot after the harvest of crop, during the years.

Oil Extraction

The shells of groundnuts were broken and seeds were cleaned manually. The seeds were dehydrated by drying 105 °C for three days in a drying oven. For each sample, 20 g of seeds were ground with a homogenizer (Heidolph Silent Crusher M) in 50 ml of petroleum and transferred to a thimble topped with cotton. Oil was extracted with a Soxhlet apparatus (Gerhardt, model 173200, EV, Germany) using with petroleum ether (40-60 °C) and it was boiled for 4 h. The solvents were removed under reduced pressure in a rotary flash evaporator (Heidolph, model Laborota 4000, Germany). Oil content was calculated by using these formulas:

$$\text{Oil content (\%)} = \frac{100 \times \text{Weight of oil extracted (g)}}{\text{weight of sample}}$$

pH, EC, OC, Available N, P and K Content in soil

Analysis of soil were done for pH (Jackson 1973) [19], Electrical conductivity and organic carbon (Walkley and Black 1934) [46], available N (Subbiah and Asija 1956) [41], available P_2O_5 (Olsen *et al*. 1954) [29], and available K_20 (Hanway and Heidel 1952) [15].

Estimation of N, P and K uptake

For the estimation of nutrient uptake for grain samples were analyzed through standard procedure for analyzing the nitrogen, phosphorus, and potassium. In this method, grain samples were dried at 60 ^{0}C, and finely ground with 0.5- mm sieve. Nitrogen content in grain was determined by digesting the samples in sulphuric acid (H_2SO_4) with the help of digestion accelerator (K_2SO_4 and $CuSO_4$, 20:1) using Kel-Plus analyzer (Pelican Equipment's, Chennai, India) as described by Jackson (1973) [19], and the digest was steam distilled with concentrated 40% NaOH. The amount of liberated NH_3 was absorbed with 4% boric acid and titrated with 0.02 N H_2SO_4. The grain samples were digested by di-acid mixture (HNO_3: $HClO_4$, 10:4) on hot plate as described by Blanchar *et al.* (1965). The phosphorus was estimated by Ammonium Vanadomolybdate solution with the aid of spectrophotometer at wavelength 760 nm (Page *et al*. 1982) using UV-Visible spectrophotometer (Systronics 167; Systronics India Ltd., Ahmedabad, India). The straw and grain samples for K determination carried out by using di-acid method (10:4 mixture of HNO_3: $HclO_4$), and digested samples was estimated by flame photometer (Systronics 128;

Systronics India Ltd., Ahmedabad, India), with methodology followed by Jackson (1973) [19]. The N, P, and K uptake was calculated from the nutrient concentration in grain and its yield. The N, P and K content in grain multiplied by grain yield (oven-dry basis). The statical analysis was done through SPSS 16 and methodology followed by Gomez and Gomez (1984) [21].

Results and Discussion

Chemical properties of soil, oil content and NPK uptake in groundnut

The data pertaining regarding major nutrients, secondary nutrients and their uptake, and other quality parameter like oil content are presented in table (3).

Nitrogen, Phosphorus and Potassium content in soil (kg ha^{-1})

Across various gypsum application methods, soil profile N, P and K content was found to be significantly lower in control in comparison to other gypsum application methods, which were statistically at par with each other. Whereas, other treatment was statistically similar due to NPK dose was also similar. However, NPK content in soil was significantly lower in control plot due to no NPK was applied in these treatments.

Secondary nutrients (kg ha^{-1})

Across various gypsum application methods, soil profile S content was found to be significantly lower in control in comparison to other gypsum application methods. Sulphur is required at 0.1–1.0% (on dry weight basis) for plant growth and development (Gaafar *et al*., 2012) [48]. The increasing reduction in the emission of S in natural system, use of fertilizers (NPK) lacking S such as urea, di-ammonium phosphate instead of ammonium superphosphate, in addition to leaching of sulphate ions deeper into the soil profile cause limited phyto-availability of this building block. In present scenario, S deficiency seems to be an emerging problem that resulted into decrease in quality and quantity of crop. In plants, about 90% S is present as cysteine (Cys) and methionine (Met), which is essential in the formation of sulfhydryl (-SH) and disulfide bonds (S-S) of proteins and enzymes possess thiol groups at their active centers (Yu *et al*., 2018). Soil profile S content was found to be significantly lower in T_1G_{100} in comparison to T_2 $G_{200,}$ T_3G_{300} and T_4 G_{400}. However, soil profile S content in T_2 G_{200}, T_3 G_{300} and T_4 G_{400} were at par with each other. Across various gypsum application methods, the calcium content was found to be significantly lower in control compared to other treatments. However, soil profile ca content in T_1 G_{100}, T_2 G_{200}, T_3 G_{300} and T_4 G_{400}were at par with each other. Meanwhile, developing fruit is below the soil surface, which unable to transpire and receive Ca from the shoot. Since, adequate Ca cannot be received from the plant, and must be absorbed by the pod directly from soil solution (Sumner *et al*., 1988) [42]. Despite, Ca moves through the plant in the xylem from roots to shoots along the transpiration stream (Skelton and Shear, 1971) [40], and has very limited movement in phloem tissue. Thereby, Ca availability in soils solution within root zone (0-15 cm depth) significantly increased after avocation various treatments of gypsum due to diffusion and mass flow under sufficient level of soil moisture under *kharif* season which enable to enhance the Ca availability within the surface soils. Besides this, nutrient enrichment (N, P, K and Ca) may also be considered another approach to minimize the effects of as toxicity in plants. Calcium has been shown to stabilize cell membrane surfaces, prevent solute leakage from the cytoplasm, maintain water status, photosynthesis, transpiration rate and regulate plant hormone metabolism (Ahmad *et al*., 2016; Naeem *et al*., 2018; Singh *et al*., 2018) [1, 27, 39]. Calcium not only regulates the cell metabolism but is also a well-known secondary messenger that transduces signals to carry out the basic metabolism of plants (Li *et al*., 2016; Aldon *et al*., 2018; Gao *et al*., 2018) [22, 3, 14]. In recent years, considerable interest has been focused on the role of Ca in protecting plants under adverse environmental conditions (Siddique *et al*., 2012; Ahmad *et al*., 2015, 2016; Li *et al*., 2016; Aldon *et al*., 2018; Gao *et al*., 2018) [37, 2, 1, 22, 3, 14] by inducing antioxidant enzyme activities and reducing lipid peroxidation of cell membranes (Naeem *et al*., 2018) [27].

Oil content (%)

Across various gypsum application methods, oil content in groundnut was found to be significantly lower in control in comparison to other gypsum application methods. Oil content in $T_1G_{100,}$ T_2G_{200} and T_3G_{300} were at par with each other. However, oil content in $T_4G_{400}$was found to be significantly superior with each other. The nutritional quality of groundnut is strongly affected by growing area, genotypes, soil structure and climate conditions Hassan and Ahmad (2012) [16]. The oil content and fatty acid composition of groundnut have been investigated in many studies with use of different genetic resources under different environmental conditions Hassan and Ahmad (2012) [16] and Dong *et al*. (2015) [10].

Major nutrients uptake (kg ha^{-1})

Across various gypsum application methods, nitrogen uptake in groundnut was found to be significantly lower in control in comparison to other gypsum application methods. Groundnut nitrogen uptake in T_2G_{200}, T_3G_{300} and T_4G_{400} were statistically at par with each other. However, groundnut nitrogen uptake in T_1G_{100} was significantly lower than inT_2G_{200}, T_3G_{300} and T_4G_{400}. Organic matter and gypsum improved water holding capacity and provides slow-release property, all nutrients from the fertilizer water will be supplied to the plant. Under aerobic condition, soil bacteria will readily transform protein-borne N to $NH4^+$ (ammonification) and $NO3^-$ (nitrification) (Roy *et al*., 2006). If the N uptake rate is slower than the rate of ammonification and nitrification, then $NO3^-$ will be subject to leaching and/or denitrification (Kim and Owens, 2010) [20]. According to Brockel and Hahn (2004) [7], stabilized fertilizers are able to reduce $NO3^-$ leaching by increasing the lifetime of $NH4^+$ N to be retained in the soil from more than one week under normal conditions to 6–10 weeks. Across various gypsum application methods, phosphorus uptake in groundnut was found to be significantly lower in control in comparison to other gypsum application methods. However, groundnut phosphorus uptake in $T_1G_{100,}$ T_2G_{200}, T_3G_{300} and T_4G_{400} were at par with each other. P deficiency is a major growth-limiting factor in many acidic soils. Inadequate P supply results in decreased synthesis of RNA – the protein maker – leading to depressed growth (Hue and Silva, 2000) [17]. The amount of P is either inherently low or present in the forms that are unavailable to plants due to high P-fixation by Fe and Al oxides and hydroxides in the clay fraction of soil (Zulkifli *et al*., 2003) [50]. Across various gypsum application methods, potassium uptake in groundnut was found to be significantly lower in control in comparison to other gypsum application methods. Potassium uptake in groundnut was significantly higher inT_4G_{400}in comparison to $T_1G_{100}$and T_3G_{300}but was statistically similar toT_2G_{200}. Potassium uptake in groundnut in case of $T_1G_{100}$and $T_3G_{300}$and or T_2G_{200} andT_3G_{300}were statistically similar respectively. The winery clay wastes show otherwise as are affected by the original available K content and uptake proportionately with the higher rate of potassium applied (Novoa-Munoz *et al*., 2008; Pateiro-Moure *et al*., 2009 and Fernandez-Calvino *et al*., 2015) [28, 30, 13]. In these studies, the exchangeable Ca and S contents remain largely unaffected lastly. Loh *et al*. (2015) [23] reported that the no research has been conducted so far on its likely effects on soil-plant system interaction and uptake. In summary, gypsum is highly capable of increasing the soil N, P and K, thus endowing it with considerable potential as a substitute for conventional fertilizers.

Conclusion

The results of this study can be concluded that gypsum application in soils significantly improved the oil content and its quality parameters in the groundnut. The significant variation was observed towards physical and chemical properties in soils after advocation of various treatment of gypsum which could be governed the ability of Ca and Supplied via gypsum to flocculate soil particles. Thereby, soil physical condition act as halts for their better nutrient uptake, proper infiltration and aeration, and enormous increased the N, P and K availability because of their favorable pH for the maximizing the ideal crop growth and its quality attributes in groundnut. Despite being gypsum offers calcium and sulphur which is needed to flocculate soil particles in alkaline soils, and enhance favorable soil structure for root growth, air and water movement. It is, therefore, concluded that Ca and S primarily from gypsum acted as a catalyst for improved soil and oil quality of groundnut. We, therefore, recommend a combination of NPK and gypsum at the rate of 25:50:20 kg $ha^{-1}$and 400 kg ha^{-1}gypsum play pivotal role for significant contribution in physico-chemical properties and quality improvement in groundnut. These results enable to validate the various physical environments under varsity of soils which act as milestone for various famers community, researcher's, academia and various stake holder, and ultimately improved the socio-economic conditions of the farmers.

Table 3: Effect of different treatments on physio-chemical properties, available major nutrient and secondary content in soils with influence of test crops

Treatments	pH (1:2.5)	EC (dsm^{-1})	OC (%)	Nitrogen	P_2O_5	K_2O	Calcium	Sulphur
				kg ha^{-1}			mg kg^{-1}	
T_0G_0	7.52	0.15	0.32	173.01	22.68	164.65	1.23	10.95
T_1G_{100}	7.66	0.16	0.33	180.54	25.52	179.41	2.58	13.45
T_2G_{200}	7.68	0.16	0.34	182.85	26.61	177.75	2.58	14.90
T_3G_{300}	7.70	0.15	0.36	190.29	27.18	174.93	2.60	14.95
T_4G_{400}	7.43	0.16	0.36	197.83	27.99	180.91	2.65	15.23
S.Em±	0.18	0.007	0.015	2.46	0.85	3.14	0.11	0.32
C.D. P= (0.05%)	NS	NS	NS	6.38	2.26	8.42	0.31	0.86

T_0G_0 = Control plot, T_1G_{100}=NPK (25-50-20) + Gypsum @100 kg ha^{-1}, T_2G_{200} = NPK (25-50-20) + Gypsum @200 kg ha^{-1}, T_3G_{300} = NPK (25-50-20) + Gypsum @300 kg ha^{-1}, T_4G_{400} = NPK (25-50-20) + Gypsum @400 kg ha^{-1}

Table 2: Effect of different treatments on nutrient uptake and oil content with influence of test crops

Treatments	Nutrient uptake (kg ha^{-1})			Oil content (%)
	N	P	K	
T_0G_0	129.08	12.43	61.15	44.63
T_1G_{100}	136.45	15.08	65.73	46.13
T_2G_{200}	137.88	15.25	66.88	47.25
T_3G_{300}	137.93	15.75	66.35	46.68
T_4G_{400}	138.20	15.30	67.55	47.30
S.Em±	0.40	0.61	0.65	0.38
C.D. P= (0.05%)	1.10	1.81	1.93	1.12

T_0G_0 =Control plot, T_1G_{100} = NPK (25-50-20) + Gypsum @100 kg ha^{-1}, T_2G_{200} = NPK (25-50-20) + Gypsum @200 kg ha^{-1}, T_3G_{300} = NPK (25-50-20) + Gypsum @300 kg ha^{-1}, T_4G_{400} = NPK (25-50-20) + Gypsum @400 kg ha^{-1}

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