EFFECT OF SOIL AMENDMENTS ON PRODUCTIVITY OF GROUNDNUT AND SOIL PROPERTIES- A REVIEW

ABSTRACT

Although India is steadily progressing in oilseeds production, but the average yields of most of the oilseeds like groundnut are still extremely low when compared to those prevailing in other countries of the world. This is because oilseeds are cultivated mostly in marginal and sub-marginal land of semi-arid areas with very less management, hence remain vulnerable to vagaries of nature. Among oilseed crops groundnut is an important source of vegetable oil and protein. Lack of appropriate management practices leads to decreased yields of the crop. Applications of amendments like gypsum and dolomite based on soil pH is necessary to provide a better environment for roots and plant growth.

INTRODUCTION

Groundnut (*Arachis hypogaea* Linn) is one of the Leguminoceae family crop originated in South America and is being cultivated in tropical, subtropical and warm temperate regions of the world. *Arachis hypogaea*, derived from two Greek words *Arachis* meaning a legume and *hypogaea* means below the ground which refers to the formation of pods in the soil. This is an annual herbaceous legume and is a self-pollinated crop. Groundnut is also known as wonder nut, poor man's cashew nut, earthnut, monkey nut, peanut, poor man's almond, moong phali, and goober. Cultivated groundnut has two subspecies, *hypogaea* (Virginia or runner), *fastigiata* (Valencia), and *Vulgaris* (Spanish) botanical variety groups.

Groundnut is the world's 13th most important food crop, 3rd largest vegetable protein source, and 4th largest vegetable oil source. There is commercial appeal to almost every portion of groundnut, oil extraction (80%),seed (12%), edible purpose (6 %) and export purpose (2 %). Groundnut kernels contains oil (42-50 %), protein (26 %), carbohydrates (18 %), starch (11.5 %), soluble sugar (4.5 %), crude fibre (2.1 %) and is also a rich source of riboflavin, thiamine, nicotinic acid and vitamin E (Naresha *et al.,* 2018). It's a dietary source of calcium, iron, zinc, magnesium, phosphorus and potash. Its high protein, unsaturated fats, carbohydrates, vitamins and mineral contents make it an important dietary component in many countries. Groundnut cake contains N (7-8 %), P (1.5 %), K (1.2 %), carbohydrates (22-30 %), proteins (45-60 %), minerals (4.0-5.7 %) and crude fibre (3.8-7.5 %) (Bairagi *et al.,* 2017).

In India groundnut is cultivated in 4.73 million hectares area with 6.72 million tonnes of total production and with 1,422 kg ha^{-1}productivity. Gujarat ranks first in area with 1.59 million hectares and 2.20 million tonnes production with 1,382 kg ha^{-1}productivity. With 3,199 kg ha^{-1}, Puducherry stands first in productivity followed by West Bengal (2,788 kg ha^{-1}) and Tamil Nadu (2,718 kg ha^{-1}). Gujarat tops with 27.87 per cent of total production followed by Andhra Pradesh 24.19 per cent, Tamil Nadu 14.84 per cent and Karnataka 10.95 per cent. Maharashtra, Madhya Pradesh, Rajasthan, Odisha, Uttar Pradesh and West Bengal are other groundnut producing states (Anon., 2019).

Groundnut (*Arachis hypogaea* L.) occupies first position among all the oilseed crops in India, accounting for over 28 percent of the country's acreage and 32 percent of the country's production. India 's annual groundnut productivity is 1,422 kg ha^{-1}, far less than the world average of

1,600 kg ha^{-1}(Anon., 2019). Reasons for low productivity are attributed to several production constraints which include poor and imbalanced nutrition and cultivation on marginal lands. It is therefore necessary to improve the nutritional aspects so as to obtain better productivity. In fact, balanced fertilizer use is essential not only for increasing the production of groundnut, but even for maintaining the present production levels.

Addition of soil amendments improve the physico-chemical properties of the soil and provide congenial conditions for the growth of crop. Soil amendments provides better environment for roots and plant growth, which includes the improvement of soil structure and water holding capacity, availability of nutrients and the living conditions for soil organisms, which are important for plant to grow (Stauffer *et al.*, 2019).Application of soil amendments was found to improve the physical and chemical properties of soil and increase the yield and quality of the groundnut (Mayalagu, 1983; More and Nalawade, 1993). Dolomite and gypsum being constituents of Ca nutrient, which is important for better pod formation and development can be applied as amendments to the soil which enhances the physico-chemical properties of the soil besides meeting the calcium requirement of groundnut.

Dolomite ($CaCO_3$. $MgCO_3$) is a double carbonate salt with an alternate structural arrangement of calcium and magnesium ions. It contains 21.73 per cent calcium, 13.18 per cent magnesium. The dissolution and chemical reaction of dolomite in the soil can be explained as follows:

$$MgCa(CO_3)_2 + 2H_2O + 2\ CO_2 \rightarrow Mg^{+2} + Ca^{+2} + 4\ HCO_3^-$$

Dissolution of dolomite provides calcium (Ca^{+2}) and magnesium (Mg^{+2}) in the soil solution resulting in higher base saturation. At the same time, aluminum ($A1^{+3}$) ions are replaced by Ca and Mg and are neutralized by OH^{-} ions. Furthermore, Ca and Mg combine with $HCO3^{-}$ and lead to $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ formation. As a consequence, dolomite application increases pH of acidic soils (Paradelo *et al.*, 2015).Dolomite is superior high free lime and widely used to increase soil pH and soil calcium levels (Rogers, 1948; Sullivan *et al*., 1974; Yang, 2015). Dolomite enhances the soil's physical, chemical and biological conditions, neutralizes soil acidity and decreases fertilizer costs by enhancing the availability of nutrients to plant roots, so less fertilizer is needed. Dolomitic lime addition is needed to increase the availability of calcium and magnesium as well as to increase the concentration of basic cations like potassium, calcium and magnesium (Barchia, 2006).

Gypsum is a soluble source of the essential plant nutrients, calcium and sulfur, and can improve overall plant growth. Gypsum being an amendment can also improve the physical properties of some soils (especially heavy clay soils). Such amendments promote soil aggregation and can help prevent dispersion of soil particles, reduce surface crust formation, and promote seedling emergence, and increase water infiltration rates and movement through the soil profile. It can also reduce erosion losses of soils and nutrients and reduce concentrations of soluble phosphorus in surface water runoff. Chemical properties improved by application of gypsum include the mitigation of subsoil acidity and aluminum toxicity. This enhances deep rooting and the ability of plants to take up adequate supplies of water and nutrients during drought periods (Ullah *et al.*, 2019).

Dissolving reaction of gypsum in soil can be expressed as:

$$CaSO_4.2H_2O \rightarrow Ca^{2+} + SO_4^{2-} + 2H_2O$$

Application of gypsum can reduce dispersion and promote flocculation of soils. Flocculation is a necessary condition for the formation and stabilization of soil structure. This increases water infiltration and percolation (Norton, 2008), thus reducing soil erosion and improving water quality. Groundnut response to gypsum, as with any other fertilizer, depends on the fertility status of the soil(Chikowo ,1998).Gypsum besides supplying Calcium and Sulphur, causes micro-acidification of soils which slightly lower down the pH of soil and increases the nutrient availability (Alcordo and Rechcigl 1993). Gypsum will change soil pH very slightly, yet it can promote better root development of crops, especially in acid soils, even without a big pH change. This is because the gypsum counteracts the toxic effect of soluble aluminium on root development. Gypsum can also improve soil structure. Adding gypsum to soil reduces erosion by increasing the ability of soil to soak up water after precipitation thus reducing runoff. It also reduces phosphorus leaching (Fisk, 2019).

Effect of amendments on soil properties after harvest of Groundnut

Bado *et al.* (2012) from Africa showed that combined application of NPK with manure or dolomite decreased exchangeable acidity and maintained soil pH and base saturation at same levels like those of original soil as compared to mineral NPK fertilizers alone. On the contrary, NPK fertilizer alone tend to increase exchangeable acidity, lowering pH and base saturation.Shamshuddin *et al.* (2012) from Australia reported that pH increased from 3.71 to 6.54, with application of ground magnesium limestone at the rate of 8 t ha^{-1}over control and other treatments.Sutriadi and Setyorini (2012) from Bogor Indonesia conducted an experiment in *Inceptisols* (pH 4.3) and reported that application of NPK (50 kg urea, 200 kg SP-36 and 150 kg KCl per hectare) + dolomite at 3200 kg ha^{-1}recorded highest soil pH (6.2), calcium (17.54 cmol ± kg^{-1}) and Mg (26.44 cmol ± kg^{-1}) after harvest of groundnut over control. He showed that there is very significant correlation between dolomite plus rates and soil pH after harvesting of groundnut. The more excessive dolomite plus rates were applied to the soil, the more bases (Ca, Mg) were added to soil, furthermore they would substitute Aluminium, hence increasing the pH of the soil. Thilakarathna *et al.* (2014) showed that pH, EC and CEC were increased (4.1 to 4.8), (216 to 260 EC µ S cm^{-1}) and (6.3, 7.7 C mol kg^{-1}) respectively at initial and final stages respectively with gypsum 250 kg ha^{-1}over control. The pH and EC values were slightly increased after five days of applying gypsum and slightly decreased at harvest. CEC also increased with applying gypsum and slightly decreased at harvest.Warren (2011) observed that the gypsum will improve the pod filling without changing the soil pH. Bairaghi *et al.* (2017) from Allahabad, Uttar Pradesh found that in *Inceptisols* (pH 7.32) application of 0% NPK + 50% Gypsum recorded lowest bulk density (1.02 g cc^{-1}) particle density (2.25 g cc^{-1}) and EC (0.629 dS m^{-1}) whereas application of 50% NPK + 100% Gypsum recorded highest pore space (50.98%) pH (7.37) and organic carbon (0.82%) over control.Application of dolomite at the rate of 4 t ha^{-1} resulted in increased pH from 4.8 to 6.9 over the control (0 t ha^{-1} dolomite) with 50% peat and 50% mineral soil in Indonesia. (Pamungkas *et al.* 2017).Naresha *et al.* (2018) concluded that in sandy loam soils (pH 7.52) of Rajendra Nagar, Hyderabad, lowest EC (0.146 dS m^{-1}) and highest pH (7.41) and organic carbon (0.527) were observed with application of phosphogypsum at the rate of 250 kg ha^{-1}(half as basal and half at flower initiation stage) over control.

Effect of soil amendments on growth parameters of groundnut

Results of an experiment conducted in Indonesia (*Inceptisols*) showed that highest plant height at 28 DAS of groundnut was recorded with application of 50 kg of urea, 200 kg of SP-36, 150 kg of KCl and 3200 kg of Dolomite plus in a greenhouse experiment. Increasing of dolomite plus rates to be 3,200 kg ha^{-1} at 28 DAP had a significant effect with respect to plant height as compared to 200 kg ha^{-1} and 1,600 kg ha^{-1} dolomite plus. Rates of dolomite plus 200-800 kg ha^{-1} did not showed significant difference. It can be concluded that the best dolomite plus rate for increasing plant height was 1,600 kg ha^{-1}. Dolomite plus (30.52% CaO, 17.11% Mg and 1.35% P_2O_5) was applied 7 days before planting of groundnut by stirring evenly in the soil. Sutriadi and Setyorini (2012). Widodo *et al.* (2017) reported that higher nodules per plant (64.88) were registered when dolomite at 5.36 t ha^{-1} was applied but increased doses of dolomite above 5.36 t ha^{-1} are likely to decrease the nodule number at Indonesia in *Ultisols*. According to Silahooy (2012), the numbers of nodules was strongly influenced by soil acidity, because acidic soil will affect the growth of *Rhizobium* species. *Rhizobium* bacteria can grow well at a pH optimum of 5.5-7.0. Soil pH for activity of *Rhizobium* renders a number of nodules and more nodules will increaseplant growth (Agistia *et al*., 2006).A greenhouse study was carried out in Philippines in which highest plant height was registered with application of chicken manure at 10 tonnes per hectare + dolomite 1 tonne per hectare whereas highest number of leaves were recorded with application of chicken manure biochar at 10 tonnes per hectare + dolomite at 1 tonne per hectare over the control and other treatments (Arangote *et al.* 2019). Mandal *et al.* (2005)

from West Bengal state reported that application of gypsum at the rate of 400 kg ha^{-1} recorded statistically highest plant height over the controland other treatments in sandy loam soils. Application of gypsum at 250 kg ha^{-1} either full at sowing or half at sowing + half at 35 DAS signficantly increased number of branches per plant, LAI, root dry weight per plant and hydration ratio at 70 DAS over control during both the years of the study. Gypsum treatments had no significant effect on DMA at 45 DAS but as the crop growth advanced the DMA increased significantly. Gypsum has an edge over other sources of S for groundnut because it contains Ca (Rao and Shaktawat, 2005). Ghosh *et al.* (2015) concluded that Recommended dose (RD) of NPK+ Gypsum at 100 kg ha^{-1} (50% basal + 50% top dressing) recorded highest plant height (28.23 cm) and it was on par with RD of NPK + Lime at 20 % LR (basal) + Gypsum 50kg ha^{-1}(100 % top dressing) over the control whereas, highest branches per plant were listed with RD of NPK + Lime at 20 % LR (basal) + Gypsum 50 kg ha^{-1}(100 % top dressing) over control and other treatments in sandy loam soils of West Bengal during the *rabi* season.The result clearly revealed the specific requirement of both Ca and S for normal growth of groundnut as stated by Harris (1968) and Tandon (1991).Yadav *et al.* (2015) from Varanasi, Uttar Pradesh revealed that highest plant height and number of branches per plant are documented with application of 25:50:20 kg N:P_2O_5:K_2O ha^{-1} + gypsum at the rate of 200 kg ha^{-1} over the control. This may be attributed due to better plant development through efficient utilization of soil resources by the plant, where primary growth element was available in sufficient amount due to favorable soil conditions (Rao*et al*. 1993).Prabu (2019) conducted a field trial at Tindivanam, Tamil Nadu during *rabi* season and showed that growth parameters varied significantly in the study and revealed that distinct differences existed with reference to different graded levels of gypsum application. Application of gypsum as split doses (as basal and top dress) produced tallest plants with a height of 30 cm, followed by basal application of 400 kg gypsum (29.7 cm). There was no significant difference among the gypsum applied treatments. The control produced smallest plants (25.5 cm). The longest roots (12.2 cm) were in basal application of 400 kg gypsum and shortest noticed in control Root development and growth are primarily soil dependent and it was hindered in surface crusted *Alfisol.* In this context, intervention with gypsum application influenced the root growth by supplying calcium, which facilitated root growth by the action of soil loosening through proper aggregation in the surface crusted *Alfisol* of experimental site. The increase in growth might be attributed to better root formation due to calcium, which in turn stimulated higher absorption of N, P, K and sulphur from soil and improved metabolic activity inside the plant (Kalaiyarasan, *et al.*, 2003)

Effect of soil amendments on yield and yield parameters

Murata (2003) from Zimbabwe carried out a field study and registered that highest pod yield was recorded with calcitic lime @ 380 kg ha^{-1}over the control treatment. For all calcium sources (calcitic lime, dolomitic lime and gypsum), increasing the dose from 115 to 380 kg ha^{-1}significantly increased the pod and Kernel yields. Shelling percentage was significantly increased by calcium application and it ranged from 67 per cent in the control to 79 per cent with 403 kg ha^{-1}Ca through calcitic lime. However, increasing the calcium dose up to 690 kg ha^{-1}did not further increased yields. Bado *et al.* (2012) in Africa showed that application of 14:10:11 kg $N:P_2O_5:K_2O$ ha^{-1} with 1 tonne per hectare dolomite recorded highest kernel and haulm yields whereas lowest kernel and haulm yields were recorded in the control. Results of a greenhouse experiment in *inceptisols* in Indonesia showed that application of NPK (50 kg urea, 200 kg SP-36 and 150 kg KCl per hectare) + dolomite @ 200 kg ha^{-1} + animal manure @ 200 kg ha^{-1}recorded higher biomass dry weight whereas highest seed dry weight (was recorded with NPK + dolomite 1600 kg ha^{-1}over control. Application of dolomite plus combined with NPK fertilizer could affect the growth and yield of peanut (Sutriadi and Setyorini 2012). Dolomite plus is an ameliorant which contains dolomite and phosphate nutrient, so that it can supply magnesium, calcium, and phosphate nutrients, that are very important for formation of gynophore and for pod filling of peanut. Therefore, total pods of peanut will increase with application of dolomite plus. Besides supplying Ca and Mg nutrients, dolomite plus also increase soil pH. This increasing soil pH will increase the availability of nutrient, especially P. P nutrient in soil is fixed by Al-P and Fe-P and it is not dissolved. Increasing of soil pH will affect the exchange of OH- ion with P, so that P in H_2 PO_4^- will be released to soil solution and available for plant (Seopardi 1983). Therefore, will affect the increasing of filled pod, so that dry weight seed increased too. In Indonesia, studies showed that dolomite @ 4 t ha^{-1} recorded highest number of pods per plot, pod dry weight and seed weight over the control which recorded lowest number of pods per plot, pod dry weight and seed weight (Pamungkas *et al.* 2017). Widodo *et al.* (2017) showed that when dolomite dose of 6.45 tonnes per hectare in combination of cow manure 20 tonnes per hectare was applied to groundnut, it resulted in the highest pod weights, highest seed weight per plant and the least unfilled pods per plant over the control and other treatments.Peanut Plant can grow normally on the optimal soil pH ranged from 5.0-7.0. According to Nyakpa *et al.,* (1998) the pH of the soil that is acidic will increases the solubility of Al, Mn and Fe which can inhibit the growth of plant roots and so it interfere with the growth of the plant. Application of the dolomites and cow manure can increase soil pH to 6.40 so that soil pH is suitable for the growth and development of peanut plants. The increasing weight of the filled pod of peanuts occur because of the availability of Ca in the soil which was due to the application of dolomite. Furthermore, dolomite will promote the development of pods of peanut plants.Application of gypsum and a 25% : 75% combination of lime and gypsum (L:G 25% : 75%) increased the number of nodules, pods, and yield of groundnut. Leachates from these treatments were observed to accumulate higher amounts of aluminium, potassium, magnesium and calcium ions.The study suggested that the application of gypsum and the lime: gypsum combination at 25%: 75% improved the yield of groundnut grown on an acid soil more than the application of lime alone (Omar *et al.*, 1991).Agasimani and Hosamani (1990) concluded that application of gypsum at the rate of 500 kg ha^{-1} at pegging stage registered highest developed pods per plant, sound mature kernel per cent, 100 kernel weight, kernel yield, haulm yield, oil yield over the control in sandy loam soils of Uttara Kannada over three locations in Karnataka. The presence of soluble form of calcium in the pegging zone is important as the physiological mobility of calcium is low. Brady (1947) reported that supply of calcium for 18 days during the critical period (15 to 30 days of gynophore production) permits 80 per cent of fruit development. Mandal *et al.* (2005) documented that with application of gypsum @ 400 kg ha^{-1}, highest number of pods per plant, number of kernels per pod, 100 kernel weight, shelling percentage, pod yield, haulm yield, kernel yield were recorded during two seasons (summer & rainy season) as compared to control in sandy loam soils of West Bengal. Results of an experiment conducted in Udaipur, Rajasthan revealed that application of gypsum (250 kg ha^{-1}) half at sowing + half at 35 DAS recorded highest pod yield and haulm yield and it was on par with application of gypsum (250 kg ha^{-1}) full at sowing over the control. The results indicate that availability at Sand Ca to groundnut at an early stage of crop growth helps in the active growth and metabolism, which ultimately lead to an increase in the yield. Rao and Shaktawat (2005). Jat and Singh (2006) from Udaipur showed that application of gypsum at the rate of 250 kg ha^{-1} at sowing + 125 kg ha^{-1} at flowering statistically increased the pods $plant^{-1}$, pod and kernel yields, 100 seed weight, shelling percentage and HI over lower levels and control but statistically equivalent with 250 kg ha^{-1} at sowing + 125 kg ha^{-1} gypsum at flowering. The mean increase in groundnut pod yield with 250 kg ha^{-1} at sowing + 125 kg ha^{-1} gypsum at flowering over control was 37.2 per cent in clay loam soils. Arnold *et al.* (2014) from Georgia documented that highest pod yield and sound mature kernels per cent were recorded with application of gypsum at the rate of 1680 kg ha^{-1}over the control and other treatments. Thilakarathna *et al.* (2014) at Sri Lanka concluded that highest number of pegs $plant^{-1}$, mean pod fresh weight, mean pod dry weight, mean kernel weight and mean shell weight were recorded with application of gypsum at the rate of 250 kg ha^{-1} over control. Ghosh *et al.* (2015) opined that highest pod yield, shelling percentage and 100 seed weight were recorded with the application of Recommended dose of NPK + Lime at 20 % LR (basal) + Gypsum 50 kg ha^{-1}(100 % top dressing) and it was on par with NPK+ Gypsum @ 100 kg ha^{-1}(50% basal + 50% top dressing) over control in sandy loam soils. Highest number of pegs $plant^{-1}$ and nodules $plant^{-1}$ at 90 days after sowing, highest fresh weight of pods, dry weight of pods and haulm yield were recorded with application of 25:50:20 kg $N:P_2O_5:K_2O$ per hectare + gypsum @ 200 kg ha^{-1} over control. Increasing of the fresh weight of pod, shelling percentage and directly high nutrients absorption by pods could lead to increase of fresh pod yield at the high levels of calciumYadav *et al.* (2015). Some studies demonstrated that groundnut yield increased with applying of fertilizer including sulfur and calcium such as single super phosphate, elemental sulfur, gypsum and also ammonium sulfate in the alkali soils (Maccio *et al.*, 2002 and Sumner, 1995). Seran (2016) observed that application of 65:100:75 ($N:P_2O_5:K_2O$) kg ha^{-1} + gypsum 300 kg ha^{-1} recorded higher pods $plant^{-1}$ and found on par with application of 30:50:37.5 ($N:P_2O_5:K_2O$) kg ha^{-1} + gypsum 300 kg ha^{-1}, whereas highest air dried pod weight and air dried seed weight were recorded with application of 65:100:75 ($N:P_2O_5:K_2O$) kg ha^{-1} + gypsum 300 kg ha^{-1} over control in Sri Lanka. Sikhakhana (2016) from South Africa opined that highest pod yield, kernel yield, shelling percentage were recorded with application of gypsum at the rate of 750 kg ha^{-1}whereas highest 100 seed weight was recorded with 500 kg ha^{-1}gypsum over the control. Application of gypsum at the rate of 400 kg ha^{-1} (50% basal + 50% top dress) recorded higher matured pods $plant^{-1}$) and pod yield whereas lowest number of matured pods and pod yield were recorded in control Prabu (2019).

Conclusion:

Gypsum and dolomite being soil amendments as well as source of calcium which is the most important nutrient for pod formation and better pod filling improves the productivity of groundnut and ameliorates the soil. Gypsum was found to be effective when applied in black soils (alkaline conditions) whereas dolomite in red soils (acidic conditions). These amendments when applied to the soil neutralizes the soil pH, improves the physico-chemical conditions of the soil and creates congenial conditions for the crop growth.

References

Agasimani, C. A. and Hosamani, M. M., 1990, Effect of gypsum on the yield and quality of groundnut in rice fallow in coastal sandy soils of Uttar Kannada district of Karnataka. *Karnataka. J. Agric. Sci.*, 3(1&2): 15-189.

Agistia, I. and Hapsari, R. I., 2006, The influence of Rhizobium Indigen Applications against the growth of Soybean in *Entisol* and *Inceptisol*. *The World of Science*. 6 (2): 171-176.

Alcordo, I. S. and Recheigl, J. E., 1993, Phosphogypsum in agriculture: A review. *Advances in Agronomy*. 49, 55-118.

Anonymous, 2019, Area, production, and average yield, Directorate of Economics and Statistics, Department of Agriculture and Cooperation report, New Delhi, available on the website: http:// www.agricoop.nic.in.

Arangote, V. R., Saura, R. B. D. L. and Rollon, R. J. C., 2019, Growth and yield response of peanut (*Arachis hypogaea* L.) and soil characteristics with application of inorganic and organic fertilizers and dolomite application. *Int. J. Biosci.*, 15(6): 164-170.

Arnold, J. A., Beasley, J. P., Harris, G. H., Grey, T. L. and Cabrera, M., 2014, Effect of gypsum application rate, soil type, and soil calcium on yield, grade and seed quality of runner type peanut cultivars. *Peanut Science.*, 44:13-18.

Bado, B. V., Bationo, A., Lompo, F., Traore, K., Sedogo, M. P. and Cescas., 2012, Long term effect of crop rotations with fallow or groundnut on soil fertility and succeeding sorghum yields in the

Guinea Savannah of West Africa. Lessons learned from Long term soil fertility management experiments in Africa, pp. 27-40.

Bairagi, M. D., David, A. A., Thomas, T. and Gurjar, P. C., 2017, Effect of different levels of NPK and gypsum on soil properties and yield of groundnut (*Arachis hypogaea* L.) var. Jyoti. *Int. J. Curr. Microbiol. App. Sci.*, 6(6): 984-991.

Barchia, M. F., 2006, Peat, Yogyakarta, Gadjah Mada University press, Indonesia.

Brady, N. C., 1947, The effect of period of calcium supply and mobility of calcium in the plant on peanut fruit falling. *Proc. Soil Sci. Soc. Amer.*, 12:336-341.

Chikowo, R., 1998, Soil fertility management options for improved groundnut production in the small holder section. *M. Phil. Thesis*, University of Zimbabwe.

Fisk, S. V., 2019, Gypsum as an agricultural product. Science news. Soil science society of America.

Ghosh, A., Singh, V. J., Srihima, G., Sahoo, P. and Chakraborti, K., 2015, Effect of gypsum and lime on seed yield parameters of groundnut (*Arachis hypogaea* L.). *J. Crop. Weed.*, 11(special issue): 5-9.

Harris, H.C., 1968, Calcium and boron effects on Florida peanuts. *Tech. Bull.* 723, Florida Agriculture Experiment Station, 18.

Jat, J. L. and Singh, P., 2006, Effect of gypsum and plant growth regulators on yield attributes and yield of groundnut (*Arachis hypogaea* L.). *Internat. J. Agric. Sci.*, 2(1):228-230.

Kalaiyarasan, C., Vaiyapuri, V., Chandrasekharan, M. V. S., 2003, Effect of sulfur sources and levels on the nutrient uptake, crop quality and sulfur use efficiency in groundnut. *Annuals of Agricultural Research.* 24(3): 478—480.

Mandal, S., Samui, R. C. and Mondal, A., 2005, Growth, yield and yield attributes of groundnut (*Arachis hypogaea* L.) cultivars as influenced by gypsum application. *Legume Res.*, 28(2): 119-121.

Maccio, D., Fabra, A., Castro, S., 2002, Acidity and calcium interaction affect the growth of *Bradyrhizobium* sp. and the attachment to peanut roots. *Soil Biology and Biochemistry*. 34: 201—208.

Mayalagu, K., 1983, Influence of different soil amendments on the physical properties of heavy black soil and yield of groundnut (TMV-7) in the Periyar Vaigai command area. *Madras Agricultural Journal.* 70, 304-308.

More, S, D. and Nalawade, S. K., 1993, Effects of gypsum application on soil properties and performance of *kharif* groundnut. *Journal of Maharashtra Agricultural Universities.* 18, 421-423.

Mupangwa, W. T. and Tagwira, F., 2005, Groundnut yield response to single super phosphate, calcitic lime and gypsum on acid granitic sandy soil. Nutrient cycling in Agroecosystems, 73: 161-169.

Murata, M. R., 2003, The impact of soil acidity amelioration on groundnut production on sandy soils of Zimbabwe. *Ph. D. Thesis*, University of petroria, Zimbabwe.

Naresha, S. A., Laxminarayana, P., Suneetha, K. B. D. and Sailaja, V., 2018, Effect of irrigation scheduling and phosphogypsum levels on yield attributes, yield and available nutrients in soil after harvest of *rabi* groundnut. *Int. J. Pure App. Biosci.* 6(2): 1300-1308.

Norton, L. D., 2008, Gypsum soil amendment as a management practice in conservation tillage to improve water quality. *Journal of Soil and Water Conservation*, 63:46A–48A.

Nyakpa, M. Y., Lubis, A. M., Pulung, M. A., Amrah. A. G., A. Munawar, A., Hong, G. B. and Hakim, N., 1998, Soil fertility. University of Lampung, Lampung.

Omar, S. R. S., Zulkifli, H., Shamsuddin, J. Y., Zuraidah, J. E., Wynne and Elkan, G. H., 1991, Use of lime, gypsum and their combinations to improve nodulation and yield of groundnut in an acidic soil. Plant-soil interactions at low pH. 275-280.

Pamungkas, I., Turmudi, E. and Hindarto, K. S., 2017, Growth and yield response of Bambara groundnut (*Vigna subterranra* L.) to the mixed of peat and mineral soil with several dosage of dolomite. *Akta Agrosia*., 20(2): 54-60.

Paradelo, R., Virto, I., Chenu, C., 2015, Net effect of liming on soil organic carbon stocks: a review. *Agric Ecosyst Environ*., 202:98–107

Prabu, P. C., 2019, Sulphur nutrition of rainfed groundnut in red and black soils of Tamil Nadu. *J. Pharmacogonosy. Phytochemistry*. 8(3):438-440.

Rao, P. G., Sharjee, A. M., Rao, K. R., Reddy, T. R. K., 1993, Response of green gram cultivars to levels of P. *Indian Journal of Agronomy*. 14 : 2305.

Rao, S. S. and Shaktawat, M. S., 2005, Effect of organic manures, phosphorus and gypsum on nutrient uptake in groundnut. *Agropedology.*, 15(2): 100-106.

Rogers, H, T., 1948, Liming of peanuts in relation to exchangeable soil calcium and effect on yield, quality and uptake of calcium and potassium. *J. Amer. Soc. Agron.*, 40, 15-31.

Shamshuddin, J., Fauziah, I. C. and Bell, L. C., 2012, Effect of dolomitic limestone and gypsum application on soil solution properties and yield of corn and groundnut grown on *ultisols.Malaysian. J. Soil. Sci.*, 13: 1-12.

Seopardi, G, 1983, The nature and characteristics of the country. Department of Soil Science. Faculty of Agriculture, IPB. Bogor, Indonesia.

Seran, H. T., 2016, Yield and yield components of groundnut as influenced by NPK chemical fertilizers, farm yard manure and gypsum. *Bangladesh. J. Sci. Ind. Res.*, 51(4): 258-290.

Sikhakhana, G. S., 2016, Evaluation of the effect of calcium source application on groundnut (*Arachis hypogaea* L.) yield and quality in Okhahlamba local municipality, Kwazulu- Natal, South Africa, *M. Sc. Thesis*, University of South Africa.

Silahooy, 2012, The effect of Dolomite and Sp-36 against Rhizobia, N Uptake and yield Peanut (Arachis hypogaea l.) in the soil of Kambisol. Agrologia1. 1 (2): 91-98.

Singh, R. A., 2007, Effect of variable doses of potassium, Sulphur and calcium on pod yield of short duration summer groundnut (*Arachis hypogaea* L.). *Int. J. Agric. Sci.,* 3(1): 196-198.

Stauffer, B., Carle, N. and Spuhler, D, 2019, Fact sheet: Soil amendment. Available on website sswm.info.

Sumner, M. E., 1995, Gypsum as a calcium and sulfur source for crops and soils in the southeastern United States. FIPR Project # 93–01–118 Final Report, Florida Institute of Phosphate Research, Bartow, FL.

Sutriadi, M. T. and Setyorini, D., 2012, Response of peanut due to application of dolomite plus. *J. Trop. Soils.,* 17(2): 143-150.

Sullivan, G. A., Jones, G. L. and Moore, R. P., 1974, Effect of dolomitic limestone, gypsum and potassium on yield and seed quality of peanuts. Paper No. 140 of the journal series of the North Carolina state university agricultural extension service, Raleigh, N.C. 27607.

Tandon, H. L. S., 1991, Sulphur Research and Agricultural production in India (3 Edition). The Sulphur Institute. Washington, D.C. USA, pp.140.

Thilakarathna, S. M. C. R., Krithisinghe, J. P., Gunathilaka, B. L. and Dissanayaka, D. M. P. V., 2014, Influence of gypsum application on yield and visual quality of groundnut (*Arachis hypogaea* L.) grown in Maspotha in Kurunegala district of Srilanka. *Tropical. Agril. Res.,* 25(3): 432-436.

Ullah, M. A., Hyder, S. I. and Ahmed, R., 2019, Effect of gypsum application on groundnut growth and nodules under rainfed condition. *International Journal of Research in Agriculture and Forestry*. 6(10): pp, 8-13.

Warren, A. D., 2011, Gypsum as an Agricultural amendment. General guidelines. Chapter 3, School of Environment and Natural Resources, The Ohio State University.

Widodo, W., Turmudi, E. and Naibaho, V., 2017, Growth and yield responses of peanuts on dolomite and cow manure doses. *Int. J. Agri. Tech.*, 13(7.1): 1505-1516.

Yadav, R., Jat, L. K., Yadav, N. S., Singh, R. P. and Yadav, P. K., 2015, Effect of gypsum on growth and yield of groundnut (*Arachis hypogaea* L.). *Envi. Ecol.*, 33(2): 676-679.

Yang, R., 2015, Calcium availability to runner type peanuts (*Arachis hypogaea* L.) in the Southeastern United States. *M. Sc. Thesis*, Auburn Univ. Auburn, Alabam