Life Science Informatics Publications

Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences

Journal Home page http://www.rjlbpcs.com/

RJLBPCS
ISSN 2454-6348

Original Research Article **DOI: 10.26479/2020.0604.09**

A COMPARATIVE STUDY OF PHOSPHORUS, POTASSIUM, CALCIUM, MAGNESIUM CONTENT, AND GROWTH OF TWO INDIGENOUS GROUNDNUTS VARIETIES CULTIVATED IN NORTHERN GHANA

D. Asamoah[1], S. A. Abagale[2]*, I. Sackey[3], J. A. Apaseku[2], U. S. Issa[4]

1.Chemistry Department, Ghana Atomic Energy Commission, Kwabenya Accra-Ghana.

2. Department of Applied Chemistry and Biochemistry, Faculty of Applied Sciences, CK Tedam University of Technology and Applied Sciences, Navrongo -Ghana.

3. Department of Applied Biology, Faculty of Applied Sciences, CK Tedam University of Technology and Applied Sciences, Navrongo -Ghana.

4. Plant Health Division, CSIR- Crops Research Institute-Ghana.

ABSTRACT: Nutrient content and foliage growth investigations were done in two varieties of groundnuts (Red and Chinese) in a potted experiment. The germinated crops were removed at three different stages of growth and weighed fresh using analytical balance, heights were measured using a straight edge, number of leaves was counted and square areas of the leaves were also calculated using a graph sheet. Calcium and magnesium content were analysed using the Atomic Absorption Spectrometer, Potassium concentration was determined using Jenway PFP7 Flame photometer and concentration of phosphorus was determined spectrophotometerically. The Red cultivar groundnuts contained more nutrients compared to the Chinese cultivar and also had higher growth (7.91%) compared to that of the Red cultivar. There was a greater increase in phosphorus (>0.0–3.7 g/treatment) content in the Red groundnuts compared to potassium (>0.0–0.4 g/treatment), calcium (2.0-5.3 g/treatment) and magnesium (0.6-3.0 g/treatment). In the Chinese groundnuts cultivar the increase in phosphorus content (19.9 – 9.3 g/treatment) was also higher, and there were increasing contents of potassium (0.6–1.0 g/treatment), magnesium (2.3-4.7 g/treatment) and calcium (4.3-9.3 g/treatment) respectively in that cultivar. All the measured growth parameters in the Red cultivar groundnuts were higher in percentages compared to that in the Chinese cultivar. In the Chinese cultivar, percentage increases in the growth were 33.87, 32.57, 50.56 and 27.49 % for height, weight, number and square area of leaves respectively, whereas these were respectively 38.83, 54.17, 53.24 and 29.89 % in Red cultivar.

KEYWORDS: Groundnuts, cultivation, vegetative growth, nutrition, fodder.

Article History: Received: July 12, 2020; Revised: August 01, 2020; Accepted: August 10, 2020.

Corresponding Author: Dr. S.A. Abagale* Ph.D.
Department of Applied Chemistry and Biochemistry, Faculty of Applied Sciences, CK Tedam University of Technology and Applied Sciences, Navrongo, Ghana.

1.INTRODUCTION

Groundnut (*Arachis hypogea* L.) is also referred to as peanut, monkey-nut, earthnuts, goobers, pinders and manila nuts [1]. It is one of the most important cash crops known for its oilseed, food and animal feeds [2]. It contains 40 – 50 % oil and 20 – 30 % protein [3], [4]. Groundnut plants require about 500 - 600 mm of rainfall and optimum temperature for their growth and development ranges from 28 - 30 ˚C [5]. A pH of 6.0 - 6.5 is also required for growth. The crop is sensitive to salinity and high soil acidity (pH < 5) which could induce Magnesium or Aluminum toxicity [6]. However, some cultivars grow well in slightly alkaline soils with pH up to 8.0 which help in nitrogen fixation [7]. Groundnuts grow to a maximum height of 60 cm [8]. According to the Ghana Statistical Service [9], groundnut in Ghana is grown throughout the Northern and Upper East regions, where about a fifth of farmers name it as one of the most important crops [8]. The crop may be used as animal diet in the form of fodder [3], [10], seeds, straw and hay rich in protein, and has better sweetness and digestibility than other fodder [11]. The protein cake (oilcake meal) residue from oil processing is also utilized as animal feed and soil fertilizer. The oil is cholesterol free and has anti-cancer, antiviral, neuro-protective, anti-aging, anti-inflammatory and life-prolonging effects, and a number of other usefulness [12]. Water is the central molecule in all physiological processes of plants and the major medium for transporting metabolites and nutrients [13], [14], with additional importance in groundnuts [15], [16]. Nutrient uptake and transportation to the root by crop plants grown in soil is seriously affected by several factors including climate and water stress [10]. Water stress reduces nutrient absorbability and nutrients uptake by crops [17], [18]. But some recent studies indicate that climate change sometimes has limited negative impacts on peanut [19]. Most of the world's groundnut production is done under conditions of unpredictable and insufficient rainfall or water stress and this seriously affects its production [10], [20]. It also has been reported that more than half of the production area, which accounts for 90 % of groundnuts growing area in the world fall under Arid and Semi-Arid regions [21] where groundnuts are frequently subjected to drought (water stresses) or water shortage [22]. However, plants have developed various strategies to allow them survive some of these problems [23], [24]. In groundnuts water stress may result in yield loss, reduction in nutritional quality of seeds and other challenges [25], [26].

The continuous supply of minerals, which is supported by genetic make-up and available water, is very vital for plants [27]. Nutrients play multiple essential roles in crop plant mechanisms [28]. Thus, they are very important to crops and animals production [28], [29]. However, certain soils lack nutrients but in others nutrients may be present in forms the plants cannot use [24]. Magnesium, for instance, is part of chlorophyll [30] and is also important to groundnut because it helps the groundnut crop in utilizing other plant nutrients efficiently. Continuous supply and utilization of minerals is therefore very vital to plants [30].

Among other factors, internal or genetic factors of crop plants influence nutrient uptake, growth and morphophysiology [31], [32]. Thus crop species and genotypes within species are known to differ in their ability to take up nutrients [33]. Krishna [34] also reported that, the exact quantity of nutrients required by groundnut to achieve optimum growth and pod formation may vary within limits based on soil type, environment and genotype. These challenges, coupled with those of the environment challenges and lack of high yielding groundnut varieties [10] therefore call for optimization of other parameters that promote productivity of the crop. Optimization of mineral nutrition is therefore key to production of groundnuts [35]. Therefore, there is an emerging need to select between cultivated species for food and fodder among other uses.

The current study therefore investigated differences in content of some nutrients and growth of foliage between “Red” and “Chinese” groundnuts cultivars commonly grown in Northern Ghana. Differences in Ca, Mg, P and K content were determined over time of growth, and compared with growth in height, weight and number and area of leaves to establish their relations in the two varieties. Based on these relations, a preferential utility cultivar in terms of food and fodder has been proposed.

2. MATERIALS AND METHODS

Samples

Root and shoot systems of two groundnuts cultivars germinated in a potted experiment, whole plants of the groundnuts and sandy loam soil.

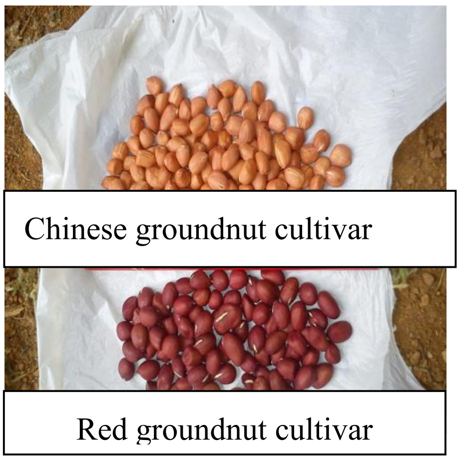

Figure 1 The two groundnuts varieties

Figure 2 Potted soil sample in improvised greenhouse

Equipment/glassware

Analytical balance, porcelain mortar and pestle, Pharo 300 Spectrophotometer, Atomic Absorption Spectrometer, Flame Photometer, digestion vessels, pH meter, graduated measuring cylinder, volumetric flask, beaker, oven, funnel, filter paper and conical flask.

Chemicals/reagents

Inorganic fertilizer (NPK 15-15-15), Gypsum (Calcium sulphate) and Epson salt (Magnesium sulphate), sulphric acid, hydrogen peroxide, nitric acid, hydrochloric acid, distilled water, P-nitrophenol (4-Nitrophenol), ammonia and ascorbic acid.

Experimental design

The experiment was conducted in a Randomized Complete Block Design in an improvised greenhouse at the premises of the "Spanish Laboratory" structure at the University for Development Studies, Navrongo. The two groundnut varieties (Chinese and Red groundnuts) were categorized as block A and block B respectively, each block comprising three treatments/replicates with four pots (1-4) in each treatment.

Sample collection

Breeder produced China and Red groundnut (Figure 1) were bought from the Navrongo Central groundnut market and shelled. The samples were identified by Mr. Roland Atara at the Navrongo office of Ministry of Food and Agriculture (MoFA) before sowing. Visibly quality seeds were selected for sowing.

Top soil was collected from Doba, [Lat (10º52′ 0″ N), Long (-1º2′ 0″W)], a suburb of Navrongo in the Kassena Nankana East district in Ghana. The soil was open-aired for 48 hours and to dryness in the laboratory. All debris was removed.

Determination of pH

The pots were filled with the dry light-textured sandy-loam soil similar to previously published procedure [36]. pH of the soil in each of the pots was determined. An amount of 2 g of the collected soil was dissolved in 10 ml of distilled water in a clean beaker to make a solution of ratio of 1:5 mass of sieved soil to volume of distilled water for pH determination.

The pH meter (Crison Basic-20) with a glass electrode was used to determine the pH. For that purpose, the pH meter was calibrated using standard buffer of pH 7.0 and 4.0. The prepared soil solution in the beaker was stirred every 5-10 minutes up to 30 minutes, the electrode was then immersed into the solution and the displayed pH of the sample was read and recorded.

Seed germination

The potted soil placed in an improvised greenhouse, was watered for three days using tap water, in other to loosen lumps. Each groundnut sample was sown in three replicates of four pots per treatment (Figure 2). Six quality seeds were sown per pot and seedlings thinned to five plants per pot by removing the weakest seedling. Sowing was in late April, 2016, when day temperatures were around

31-37ºC and night in the range of 30-35ºC. The seeds were sown at a depth of about 2 cm [33], [37]. Two (2.0) grams each of inorganic fertilizer (NPK15:15:15), Epson salt and calcium sulphate were dissolved in 2 L of tap water to give 3 g/L of solution. Different quantities of the solution were applied to each pot 10 DAS. One plant each was randomly taken from each pot of each treatment to make up the control sample before these chemicals were added. Samples for analyses were collected at three different stages (1^{st}, 2^{nd} and 3^{rd}) in addition to a control. The 1^{st}, 2^{nd} and 3^{rd}stage samples were taken for various analyses, four, six and eight days after chemical application. Water was supplied immediately to the plants at each stage beginning from the 1^{st} stage after sample collection.

Determination of height of seedling, square area of leaves, and number of leaves

The longest leaf was identified from each seedling for measurements. A 30.0 cm straight edge was used to measure height of each plant from the soil surface to the edge of the longest leaf.

The number of leaves per plant including developing leaf buds was also counted. Square areas of the leaves were also calculated by placing the leaves on a standard 2 cm graph sheet and tracing the outlines. The area of the petiole was not included in the calculations [38]. At each stage, a seedling with the longest leaf was identified in each pot and carefully uprooted for further analyses. Traces of soil and/or debris were carefully eliminated and the plant was weighed using the analytical balance (Sartorius TE601). The collected plant samples were grouped according to treatment and air dried to reduce the moisture before they were oven-dried at 80 ˚C for 24 hours. The dried samples were ground, packed into containers, sealed and labeled according to treatment for further work.

Nutrient analysis

Each packed sample was weighed (0.5 g) and transferred into a digestion vessel. 8 ml of a mixture of nitric acid (HNO_3) and hydrochloric acid (HCl) in a ratio of 1:3 respectively was added to the weighed sample. The content was mixed and heated to a temperature range of 40 - 60℃ when NO_2 gas seized to evolve. It was cooled, filtered and the filtrate transferred into a 100 ml volumetric flask. The volume was made to the mark using distilled water. The solution was used to determine calcium and magnesium using the Atomic Absorption Spectrometer (AAZ40FS) using existing procedures [39], [40] at the Ghana Atomic Energy Commission, Accra. Potassium concentration was determined using Jenway PFP7 Flame photometer at the Ecology Laboratory of University of Ghana, Accra. 0.1 g of each sample was weighed and transferred into a 250 ml conical flask. 5 ml Sulphric acid was added to the sample, the content was well mixed and allowed to sit for one hour. Heat was applied up to 80 ˚C when white fumes evolved. Hydrogen peroxide was added in drops until a clear solution was attained. The content was allowed to cool before it was transferred into a 100 ml volumetric flask and the volume made to the mark using distilled water (volume of extract). To determine P, 1.0 ml of the extract was pipetted into a 50 ml volumetric flask and 5 ml of distilled water added. One drop of P-Nitrophenol was added to the solution, after which ammonia was added until a yellow colour was obtained. One drop of stock solution A (extract) + Ascorbic acid was added to the solution. The colour changed from yellow → colorless → light blue. The solution was then topped up to the mark with distilled water. Concentration of Phosphorus was determined using the Pharo 300 spectrophotometer at the Ecology Laboratory of University of Ghana, Accra.

3. RESULTS AND DISCUSSION

Physical parameters

Table 1: pH measurements of the soils in which the groundnuts were sown

CHINESE GROUNDNUTS CULTIVAR						RED GROUNDNUTS CULTIVAR				
Treatment pH	Replicates				Mean pH	Replicates				Mean pH
	1	2	3	4		1	2	3	4	
i	6.01	5.89	6.07	5.96	5.98	5.94	5.99	6.03	6.04	6.00
ii	5.83	6.01	6.05	5.49	5.85	5.94	6.18	6.05	5.58	5.94
iii	5.73	5.71	5.64	5.51	5.65	5.98	6.09	6.29	6.03	6.09

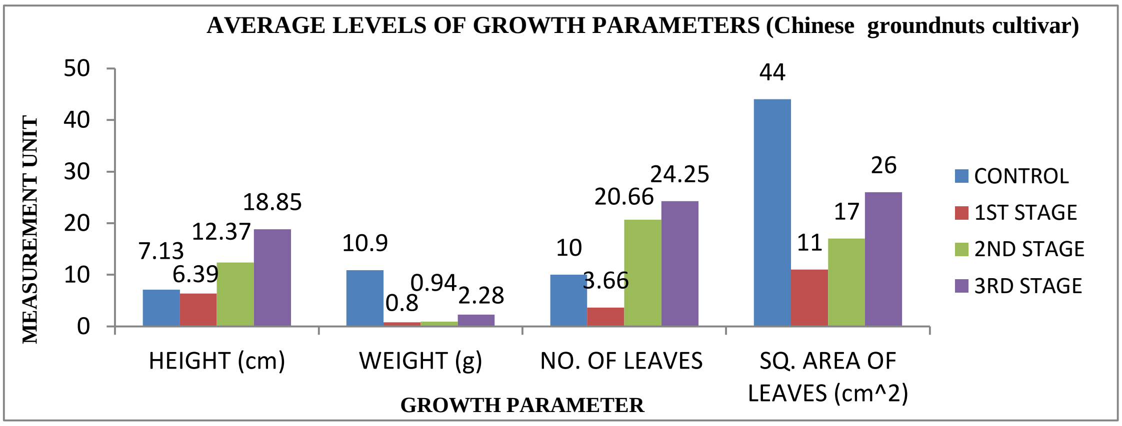

Figure 3 Average height, weight, number and square area of leaves of the Chinese groundnuts cultivar

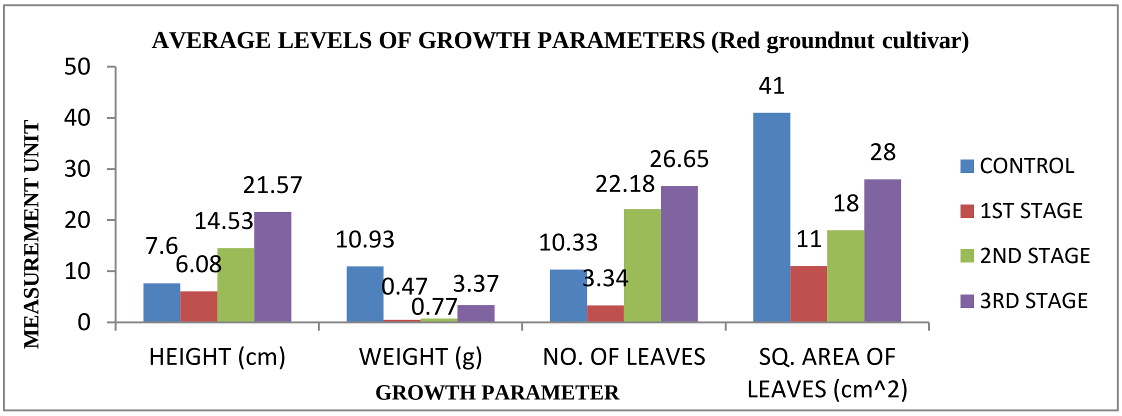

Figure 4 Average height, weight, number and square area of leaves of the Red groundnuts cultivar

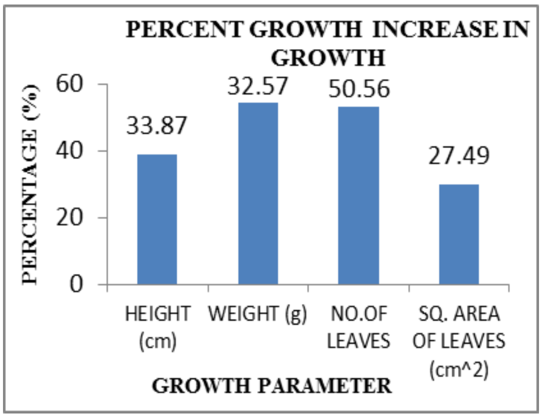

Figure 5 Chinese groundnuts cultivar

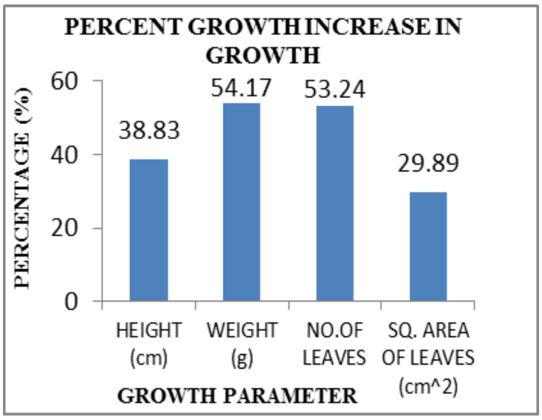

Figure 6 Red groundnuts cultivar

Chemical parameters

Nutrients

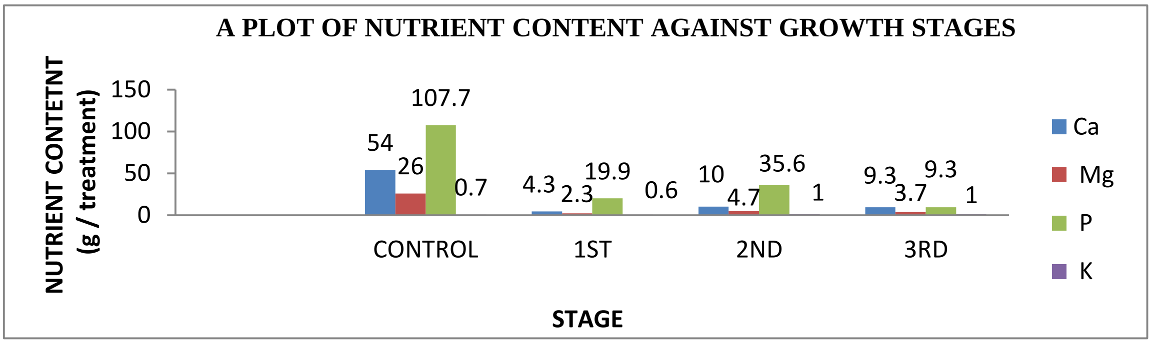

Figure 7 Average content of selected nutrients in the Chinese groundnuts cultivar

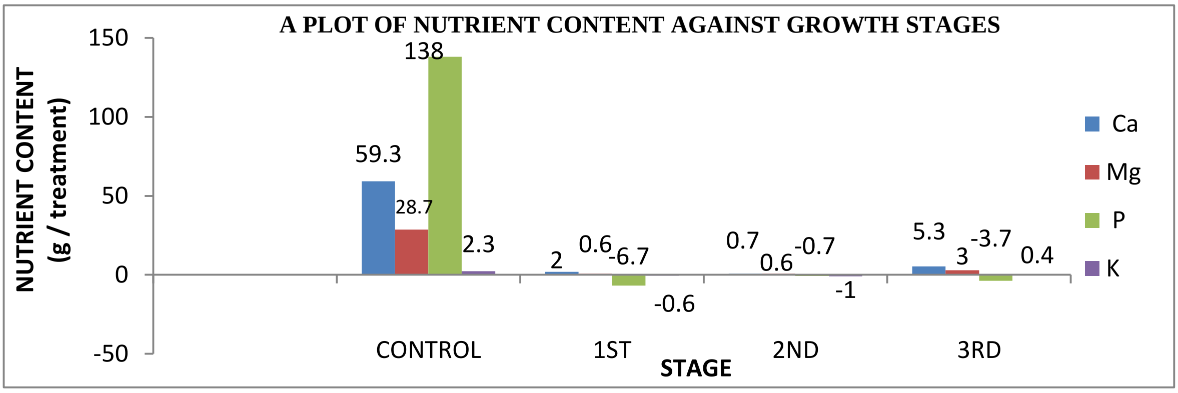

Figure 8 Average content of selected nutrients in the Red groundnuts cultivar

pH of all the soils used in the current study (Table 1) ranged from 5.49 – 6.07 in Block A, the Chinese groundnuts and from 5.58 – 6.29 in Block B, the soil used for Red groundnut. The soil in which the Chinese groundnuts were planted had a mean pH of 5.83 whiles that of Red groundnut was 6.01. According to Prasad et al. [7] the standard, is that a soil of pH 6.0 – 6.5 is required for the growth of groundnuts, though some cultivars grow well in slightly alkaline soils with pH of up to 8.0. Increased soil pH would usually decrease the rate of absorption of nutrients by crop plants [14]. In the current study, pH of the soil on which Chinese groundnuts were sown was generally slightly acidic compared to that in which Red groundnuts were sown. Red groundnut should therefore be expected to slightly absorb more nutrients as reported by earlier researchers [14]. pH of soils of both blocks in the current study was quite satisfactory and the differences may not significantly cause variation of the crops nutrient uptake. Notwithstanding the slight pH differences in soils used in the current study, the differences may not influence the crops' nutrient uptake so much. If at all, the slight differences in soil pH only had negligible differential influence on the growth. According to Schwartz [42], lower pH may not necessarily have impact on germination of groundnut but significantly may reduce seedling survival and early growth. Therefore, if the internal factors were held constant, then one could conveniently indicate that Chinese groundnut may therefore not be as suitable as Red groundnuts for cultivation in slightly acidic soil, with pH of 5.83.

Nutrient content

From figure 7, the most abundant nutrient in the Chinese groundnuts was K followed by Mg and then Ca, the least being P. However, P and K were found to be more in the Red groundnut followed by Mg and then Ca (Figure 8). Higher nutrient concentration in soil increases the opportunity for nutrient movement into the plants [42]. Phosphorus is important to plants [43], and without phosphorus, plants cannot grow even if nitrogen supply is plenty [20]. Phosphorus was reported by Sharma and Yaday [44] to play a beneficial role in legume growth though it was earlier reported [45] to adversely affect the formation of root nodules, and decrease [46] shoot length and number of leaves. It is a component of nucleic acids and high uptake supports higher grain production and earlier crop maturity [47]. When phosphorus is insufficient or deficient in groundnuts, flower production as well as size of pods reduces [46]. Phosphorus and potassium are also important in animal wellbeing, relating to functioning of the heart, skeletal and smooth muscles, and digestive system [43]. Potassium deficiency causes marginal chlorosis and early leaf dropping and death of tissue. Though groundnuts have low potassium requirement compared to other legumes, the nutrient is essential in nearly all processes needed to sustain growth and reproduction [48]. Mg and Ca are secondary nutrients which are needed in lesser amounts. Mg is required in photosynthesis as a building block of chlorophyll [30]. Presence of Mg in groundnuts also influences the effective utilization of other nutrients, and presence of Ca is essential to plant and animal development [49], [50]. Calcium is by far the most important nutrient for pod development. Insufficiency or deficiency of the nutrient in groundnuts affects formation and filling of pods [35], [51], [52] and causes darkened plumules [52]. Calcium content soil around the groundnut pods therefore leads to increased yield as well as oil and protein content of the kernel [52]. K leads to increased yield and improved quality. It also activates many enzyme systems, increases protein content of the crop, retards crop diseases, reduces respiration, prevents energy losses and aids photosynthesis and food formation [53]. The nutrients absorbed by the two groundnut cultivars (Figures 7 and 8), may have started enhancing growth of the crops. Red groundnut which took up more of the nutrients was found to have a correspondingly higher change in growth compared to the Chinese groundnuts cultivar. Nutrient absorption should contribute to plant growth and development [54]. The ability of the two groundnuts varieties to absorb K, P, Ca and Mg makes their foliage good fodder as well as provides potential for productivity and nutrition.

Number of leaves, height and square area of leaves

From figures 3 and 4, though each parameter increased through the second and into the third stages of measurement all the measured parameters in the first stage of measurement were lower than those of the control. This may be because the plants utilized some of the nutrients initially available in them to start growth, and for absorption of more nutrients from the soil. Height of germinated plants of both varieties increased with increasing weight, number as well as the square area of leaves. However, the weights of both varieties were very much reduced in comparison with the controls. This trend may probably be because the plants converted a lot of stored food in order to carry out active transport. One could suspect that the slight differences in soil pH may have also influenced the growth in a little way. According to Schwartz [42], lower pH may significantly reduce seedling survival and early growth. Therefore, if the internal factors were held constant, then one could conveniently indicate that Chinese groundnut may not be suitable for cultivation in slightly acidic soils, with pH of about 5.83. On the other hand, other environmental factors [55] which the current research may not be able to establish could have also contributed to the low growth in the Chinese groundnuts. Comparing the growth of the two cultivars (Figures 5 and 6), the percentage increase in each parameter in the Chinese groundnuts were 33.87, 32.57, 50.56 and 27.49 % respectively for height, weight, number of leaves and the square area of leaves, whereas it was respectively 38.83, 54.17, 53.24 and 29.89 % in the Red groundnuts. The Red groundnut generally had higher percentage increases in all the measured parameters. The ability of primary roots or leaves to draw absorbed nutrients from the root hairs for growth [56] was probably low in the Chinese groundnuts, thus resulting in the lower levels of nutrient content. Influences on nutrient uptake, growth and morphophysiology [32] must have contributed to the differences in nutrient content.

4. CONCLUSION

The analysis demonstrated the presence of phosphorus, potassium, calcium and magnesium in the Chinese and Red groundnuts samples used in this research. The present study has shown that the increase in nutrient content relates positively to increased growth of foliage. The most abundantly absorbed nutrient in the Chinese groundnuts was K followed by Mg and then Ca, the least being P, while P and K were found to be more in the Red groundnuts followed by Mg and then Ca. It was observed that the Chinese cultivar groundnuts contained less phosphorus compared to magnesium, calcium and potassium but more phosphorus and potassium were contained in the Red groundnut.

It was also observed that the height, weight, number of leaves and square area of leaves of the Red groundnuts were higher compared to those of the Chinese cultivar groundnuts. The high nutrient content in the Red cultivar generally contributed to 7.91 % increase in growth over the Chinese groundnuts. The percentage increase in the growth parameters were 33.87, 32.57, 50.56 and 27.49 % for height, weight, number of leaves and the square area of leaves respectively in the Chinese cultivar whereas it was respectively 38.83, 54.17, 53.24 and 29.89 % for height, weight, number of leaves and the square area of leaves in the Red cultivar. The Red groundnuts generally had higher percentages of growth in height, weight, number of leaves and square area of leaves. The Red groundnuts cultivar represents a preferable fodder crop and also portrays a higher potential for productivity and nutritive food.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No Animals/Humans were used for studies that are base of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this research are available within the article.

FUNDING

The study was funded solely by the researchers.

ACKNOWLEDGEMENT

The Faculty of Applied Sciences of the University for Development Studies provided space in the court yard of the Spanish Laboratory for the greenhouse set up and the Ministry of Agriculture, through Mr. Roland Atara identified the samples for the experiment.

CONFLICT OF INTEREST

The authors declare that there are no any financial interests or conflict of interest.

REFERENCES

1. Belel MD, Halim RA, Rafii MY, Saud HM. Intercropping of corn with some selected legumes for improved forage production: A Review. J. of Agric. Science. 2014; 6(3) : 48-62.
2. Mangasini AK, Mwanahawa LM, Arbogast GM, Neema PK. Agronomic factors limiting groundnut production: A case of smallholder farming in Taboraregion. 17th Annual Research Workshop Dar es Salaam, Tanzania. 2012; 28-29.
3. Muniappan V, Palanive S, Parvathi S, Viswanathan MB, Rajes R. Analysis of Seed Proteins in Groundnut Cultivars (*Arachis hypogaea* L.). Int. J. of Eng. Res. and Appl. 2016; 6(7): 06-10.
4. CSIR-SARI, Groundnut production guide. 2014. Retrieved on 28/08/2015.
5. Wiess EA. Oilseed crops. Blackwell Science Ltd. Paris, Tokyo, Berlin, Victoria, 2000.
6. CEFA, Good agronomic practices in Western Kenya, 2011.
7. Prasad R, Kumar M, Varma A. Role of Plant-Growth-Promoting Rhizobacteria (PGPR) in Soil

Fertility and Plant Health, 247-260. In: Role of Plant-Growth-Promoting Rhizo bacteria and Medicinal Plants, Soil Biology. D. Egamberdieva et al. (eds.), 2015.

8. Armstrong WP. The peanut: "A subterranean legume". Waynes word – peanut. Retrieved on 27/08/2015, 2009.
9. Ghana Statistical Service, Groundnut growing in Ghana. 2011; xi.
10. Javed H, Igbal J, Mateen, Z. Response of Different Cultivars of Groundnut, *Arachis hypogaea* L. (Fabaceae: Fabales) to Aphids, *Aphis craccivora* K. (Aphididae: Homoptera) in Interaction with Local Weather Factors. Pakistan J. of Zoology. 2014; 46(1): 75-81.
11. Smith S. Growing corn with companion crop legumes for high protein silage, Green book Energy and Sustainable Agriculture Program Minnesota, Dep. Agric. USA. 2002: 68-70.
12. New World Encyclopedia contributors, Peanut. 2008. Retrieved on 8/09/2015.
13. Bernacchia G, Furini A. Biochemical and molecular responses to water stress in resurrection plants, Physiologia Plantarum, 2004, 121:175-181.
14. Seyed YS, Lisar R, Motafak K, Mosharraf M, Hossain S. Ismael, MMR. Water stress in plants, causes, effects and responses. 2012; 145-186.
15. Boyer JS, Westgate M.E. Grain yields with limited water. J. Exp. Bot. 2004; 55: 2385- 2394.
16. Vadez V, Krishnamurthy L, Serraj R, Gaur PM, Upadhyaya HD, Hoisington DA, et al. Large variation in salinity tolerance in chickpea is explained by differences in sensitivity at the reproductive stage. Field Crop Res. 2007; 104(1-3): 123–129.
17. Baligar VC, Fageria NK, He ZL. Nutrient use efficiency in plants. Commun. Soil Sci. Plant Anal. 2001; 32: 921–950.
18. Fageria NK, Baligar VC, Clark RB. Micronutrients in crop production. Adv. Agron. 2002; 77: 185–268.
19. Babacar F, Heidi W, Mbaye D, Mamadou LM, Joshua DO-S, Jesse BN, Thomas G. Potential impact of climate change on peanut yield in Senegal, West Africa. Field Crops Research. 2018; 219: 148-159.
20. ICRISAT, Groundnut (Arachishypogaea L.). Hyderabad, India International Crop Research Institute for the Semi-Arid Tropics, 2011.
21. Hamidou F, Halilou O, Vadez V. Assessment of groundnut under combined heat and drought stress. J Agron. Crop Sci. 2013; 199: 1-11.
22. Reddy TY, Reddy, V.R., Anbumozhi, V. Physiological Responses of Groundnut (*Arachis hypogea* L.) To Drought Stress and Its Amelioration: A Critical Review. Plant Growth Regulation. 2003; 41: 75-88.
23. Sprent B. 60 Ma of legume nodulation. What is new? What is changing? Journal of Experim. Bot.. 2008; 59: 1081-1084.
24. Morgan JB, Connolly EL. Plant-soil interactions: Nutrient uptake. Nature Edu. Knowl. 2013;

4(8): 2.

25. Amir Y, Benbelkacem T, Hadni L, Youyou A. Effect of irrigation and fertilization on characteristics of peanut seeds cultivated near Tizi-Ouzou. J. of Agric. Food Chem. 2005; 4: 879-885.
26. Girdthai T, Jogloy S, Vorasoot N, Akkasaeng C, Patanothai A, Wongkaew S, Holbrook CC. Associations between physiological traits for drought tolerance. Plant Breeding. 2010; 129: 693-699.
27. Taiz L, Zeiger E. Plant physiology, 4th ed., Sinaneur Associates. 2006; 75-91.
28. Ashraf M, Athar HR, Harris PJC, Kwon TR. Some prospective strategies for improving crop salt tolerance. Adv. Agron. 2008; 97: 45-110.
29. Beasley J. Peanut cultivars and description, growth and development. Peanut Production Guide. University of Georgia Cooperative Extension service bulletin. 1997; 1146: 2-19.
30. Bharati G. ICRISAT. Importance of secondary nutrients, 2009.
31. Casadebaig P, Debaeke P, Lecoeur J. Thresholds for leaf expansion and transpiration response to soil water deficit in a range of sun Flower genotypes. Eur J. Agron. 2008; 28: 646-654.
32. Jones G, Ljuny, F. Subterranean space exploration: The development of root system architecture. Current opinion in plant Bio. 2012; 15: 97-102.
33. Garg BK. Nutrient uptake and management under drought, nutrient-moisture interaction. Curr. Agric. 2003; 1(8): 27.
34. Krishna KR. Nutrient Dynamics, Ecology and Productivity. Agro ecosystem of South India. Baron Walker Press, Baco Raton, Florida. USA. 2010; 427.
35. Kabir R, Yeasmin SAKM, Mominul I. Effect of phosphorus, calcium and boron on the yield of groundnut (*A. hypogaea* L.). Department of Agronomy, Bangladesh Agric. Unit, Mymensringh, Bangladesh. Intern. J. of Bio-science and Bio-tech. 2013; 5(3): 51-60.
36. Taru VB, Kyagya IZ, Mshelia SI, Adebayo EF. Economic efficiency of resource use in Groundnut production in Adamawa State of Nigeria. World J. of Agric. Sc. 2008; 4(S): 896-900.
37. Abagale SA, Apaseku J, Dawda S, Abagale M-D, and Abi LA. Biochemical relevance of sorghum and millet produced in the Kasena-Nankana districts of Ghana, and some of their by-products to food, nutrition, health and wealth of the people. Int. J. Chem. and Mat. Res. 2013; 1(2): 14-24.
38. American Association for the Advancement of Science, Finding the surface area of a leaf. Science Net Links. 2016. Retrieved on: 4/07/2016.
39. Baidya NP, Soumen C, Chismita D, Singha P, Pandeya BK, Girib SS. Mineral Assay in Atomic Absorption Spectroscopy. The Beats of Natural Sciences. 2014; 4:1.
40. Wade LB, Johnson CM. Determination of Calcium and Magnesium in Plant Material and

Culture Solutions, Using Atomic-Absorption Spectroscopy. Applic. Spec. 1966; 20: 209-211.

41. Gill RIS, Singh B, Kaur N. Productivity and nutrient uptake of newly released wheat varieties at different sowing times under poplar plantations in North-Western India. Agroforestry systems. 2009; 76(3): 579-590.
42. Schwartz J. Nitrogen Management, Plant Health. 360 Yield Center. 2015. Retrieved: 30/06/2016.
43. Sigel A, Sigel H, Sigel RKO. Interactions between Metal ions and Human Diseases. Springer Sc. and Bus. Media. 2014; 349.
44. Gervey A. Fertilizer and agriculture. IFA lid. 28 Rue Maberf 75008. Paris. 1987; 37-95.
45. Sharma BM, Yaday JSP. Availability of phosphorus to groundnut as influenced by phosphoric fertilization and irrigation regimes. India J. Agric. Sci. 1997; 46: 205-210.
46. Seshadri CR. Groundnut a monograph. Oil seeds committee, Indian Central, Hyderabad. 1962.
47. Basha SKN and Rao GR. Effect of phosphorus on growth and metabolism in peanut. India Journal of plant physiology. 1980; 23: 273-277.
48. Beegle DB, Durst PT. Managing Phosphorus for Crop Production. Penn State College of Agricultural Sciences, Agronomy Facts 13, UCO55. Updated 2017; 1.7.
49. Johnston AE. Understanding Potassium and its use in Agriculture. Potassium in Agriculture: Potassium in plants, animals and humans. Published by: European Fertilizer Manufacturers' Association, Avenue E. van Nieuwenhuyse 4, B-1160 Brussels Belgium. 2015. Retrieved: August 2018.
50. Berdanier CD, Dwyer JT, Heber D. Handbook of Nutrition and Food, 3rd ed., CRC Press. 2016; 211-226.
51. Singh F, Oswalt DL. Groundnut production practices. Skill development series. ICRISAT. No. 1995; 3: 9.
52. Ntare BR, Diallo AT, Ndjeunga AJ, Waliyar F. Groundnut seed production manual. Patancheru 502324, Ed. Andhra Pradesh, India. ICRISAT. 2008.
53. Van Brunt JM, Sultenfuss JH. Better Crops With Plant Food. In: Functions of Potassium in Plants. Editors: Armstrong DL, Griffin KP, Danner M. 1998; 82(3): 4-5.
54. Atieno J, Li Y, Langridge P, Dowling K, Brien C, Berger B, Varshney RK, Sutton T. Exploring genetic variation for salinity tolerance in chickpea using image-based phenotyping. Scient. Reps. 2017; 7:1300-20
55. Gang C, Suping W, Xiang H, Juan H, Lei D, Lihong Z, Lixia Y. Environmental factors affecting growth and development of Banlangen (Radix Isatidis) in China. African J. of Plant Sc. 2015; 9(11): 421-426.
56. Silva EB, Ferreira EA, Pereira GAM, Silva DV, Oliveira AM. Peanut Plant Nutr. Absorption and Growth. 2017; 30 (3): 653- 666.