

Research Article

Effect of Temporal Application of Gypsum on Mineral Uptake and Economically Important Morphometric Traits in Groundnut (*Arachis hypogaea* L) under Rain-fed Conditions

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Abstract | Groundnut (*Arachis hypogaea* L) is an important cash crop grown in semi-arid regions of Pakistan. Groundnut is a good source of protein, edible oil, and vitamins. A gradual decline in groundnut yield has been reportedly subjected to various agro-climatic conditions and soil fertility problems. In this study, various regimes of gypsum application and its effect on groundnut yield, morphometric parameters, and minerals (Ca, K, P) concentration in root and shoot have been examined. A newly released Pothowar groundnut variety (Variety name) was grown in 3 replications with 5 m row length using a randomized complete block design. Five different treatments were applied in two split doses i.e. T1 (0 %:100 %), T2 (25 %:75 %), T3 (50 %:50 %), T4 (75 %:25 %), and T5 (100 %:0 %) at the time of sowing and pegging compared with Check (T0). Results showed significant differences among treatments for yield and related agronomic traits as well as mineral concentration in response to gypsum application. The highest pod yield (3522.2kg/ha), root biomass (9.03g/ plant), and nodules (382/ plant) were observed in treatment T3. The calcium concentration (0.80 %) in shoots of T3 was the highest. In the present study application of gypsum at the time of sowing and pegging was found to have a positive effect on grain yield and mineral concentration. We recommend that optimum doses of the gypsum should be applied to enhance groundnut yield.

Received | March 16, 2020; **Accepted** | October 12, 2020; **Published** | January 31, 2021

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Citation | Jahanzaib, M., N. Nawaz, M. Arshad, M. Suhaib, M. Husain, S. Saima, H. Khurshid and S.A. Khan. 2020. Effect of temporal application of gypsum on mineral uptake and economically important morphometric traits in groundnut (*Arachis hypogaea* L) under rain-fed conditions. *Pakistan Journal of Agricultural Research*, 34(1): 1-7.

DOI | <http://dx.doi.org/10.17582/journal.pjar/2021/34.1.1.7>

Keywords | Agronomic traits, Groundnut, Gypsum, Minerals, Yield

Introduction

Groundnut or peanut (*Arachis hypogaea* L.) is the second most edible oilseed crop after sunflower in terms of production. Groundnut was originated in South America and spread to other parts of the world. Currently, it is grown throughout the globe where more than 100 countries share its cultivation. The top ten producers of groundnut globally are China, India, Nigeria, United States, Sudan,

Myanmar, Tanzania, Argentina, Indonesia, and Senegal (Pandey *et al.*, 2012; Varshney *et al.*, 2013). Groundnut kernel contains 50 % edible oil, 20 % carbohydrates, 25-30 % protein, and 5 % fiber and ash making it a rich human diet (Fageria and Baligar, 1997). Furthermore, it provides minerals including calcium, phosphorus, potassium, and magnesium as well as rich source of vitamins B, E, and K. It is also rich in thiamine and niacin compared with cereals (Shah *et al.*, 2012). Groundnut can be used either in

the form of edible oil after processing of the kernels or as a shelled nut. Confectionery items or sauce, groundnut butter, and flour while its haulms are used as animal feed (Ahmad and Rahim, 2007; Shah *et al.*, 2012). As a legume groundnut also enriches the soil via atmospheric nitrogen fixation without draining nonrenewable energies or upsetting the agro-ecological balance (Nadar and Uddin, 2009). Groundnut has a distinctive fruiting habit that plays a vibrant role in the uptake of nutrients particularly Ca. The movement of Ca takes place from roots to shoots in the transpiration stream via xylem and cannot move through tissues of phloem well. Due to the below ground development of groundnut pods, it cannot receive and transpire Ca from the plant, so pods must take it directly from the soil (Sumner *et al.*, 1988). For pegging as well as pods formation and pod filling Ca is a critical element. Deficiency of available Ca causes embryo abortion leading to a significant reduction in yield (Csinos and Gaines, 1986).

Gypsum or calcium sulphate is a naturally occurring mineral moderately soluble in water (Chen *et al.*, 2005). Gypsum increases the productivity of agriculture crops and improve soil quality (Chen *et al.*, 2005; Tirado-Corbalá *et al.*, 2017) via promoting soil flocculation, reduces surface sealing and crusting, and increase infiltration rate of water (Tirado-Corbalá *et al.*, 2017). In infiltrating water, the electrolyte concentration increases due to gypsum application on the soil surface compressing electric double layer and provides calcium to exchange complex where it has selectivity over sodium and magnesium in common soils (Dontsova and Norton, 2002). Gypsum consisting of calcium and sulphur are the most essential macro-elements for plant growth and development. Calcium playing a key role in the superior growth of roots (Watts and Dick, 2014), responsible for strengthening cell wall and root tips development (Tirado-Corbalá *et al.*, 2017). Gypsum application significantly improves yield in crops including sorghum (Rocha *et al.*, 2014), and alfalfa (Tirado-Corbalá *et al.*, 2017).

Being secondary plant nutrient sulphur provide critical support in increasing yield particularly in oil seeds crops. It is critical for sulphur containing amino acids including chlorophyll, cysteine and methionine as well as coenzyme-A synthesis (Kumar and Yadav, 2007). Moreover, it also boosts vegetative

growth (Patil *et al.*, 2018). Due to prominent role sulphur it can be regarded as major nutrient. Its absence in early vegetation stage may decline plant growth and as a result pods yield. The gypsum containing little lower concentration of sulphur (15-18 %), so keeping this in consideration relatively large amounts of gypsum should be applied to meet the optimum requirements of the groundnut. The significance of sulphur in improved yield and quality in groundnut either at sowing or flowering stages has been well documented in the recent past (Abd EL-Kader, 2013; Elseed *et al.*, 2015; Gashti *et al.*, 2012; Kannan *et al.*, 2017; Pratiwi *et al.*, 2016; Yadav *et al.*, 2015), but none of these reported the comparison of gypsum application both at sowing and flowering stages. The current study was planned with the objective to optimize the gypsum doses at sowing and flowering stage to increase the groundnut yield and quality.

Materials and Methods

This experiment was led on the sandy loam soil of oilseed research program at National Agricultural Research Centre (NARC), Islamabad, Pakistan with 33.6701° N, 73.1261° E latitude and an altitude of 540 meters above the sea level. Randomized complete block design with three replications and 5 treatments *viz.* T₁, T₂, T₃, T₄, and T₅ compared with check was used as experimental design in this study. The treatments were based on the optimum dose of gypsum (500kg/ha). We split the doses into 2 times, one at the time of sowing and the other at pegging *i.e.*, T₁ (0-100 %), T₂ (25-75 %), T₃ (50-50 %), T₄ (75-25 %), and T₅ (100-0 %) compared to check (T₀) with zero gypsum application.

Effect of gypsum application on phosphorus and calcium contents

Phosphorus content/uptake (%) in roots and shoots was determined by digesting the oven dried plant samples in di-acid (HNO₃-HClO₄) followed by spectrophotometer at 470 nm analysis. Calcium content in shoot (%) was determined from the digested shoot sample via EDTA titration method.

Data analysis

Data were analysed for analysis of variance (ANOVA) using Statistix 8.1 software while heatmap and box plot were constructed using gg plot 2 and heatmap 2 packages in R language.

Results and Discussion

Shoots and roots fresh and dry weight

Significant increase was observed between fresh and dry weight after gypsum application (Table 1). Among the treatments T_3 i.e., 250kg/ha of gypsum application at the time of sowing and 250kg/ha at flowering stage greatly encouraged the root and shoot fresh weight as well as stem and root dry weight compared to other treatments and control (Table 1). Increased plant fresh and dry weight of crops by gypsum application is well-documented in the literature (Rasouli *et al.*, 2013; Rocha *et al.*, 2014), where the reason was increased area of root system, better water and nutrient absorption by plants (Caires *et al.*, 2006). Calcium is an important nutrient promoting better root growth, strengthening cell wall, and root tips development (Toma *et al.*, 1999; Watts and Dick, 2014).

Gypsum application stimulate growth and physiology in groundnut

An increase in number of leaves was observed when relatively low dose of gypsum was applied at sowing stage and high dose was applied during sprouting stage (T_2 and T_3) as compared to high dose at sowing stage and vice versa. Same trend was observed in roots and shoots length. Maximum shoot and root lengths were recorded with application of 250 kg/ha gypsum at sowing and 250 kg/ha (T_3) at sprouting time, significantly superior production was gained compared to other treatments. It was observed that T_3 treatment has significantly better effective in promoting overall growth of groundnut plants, which might be due to optimum availability of sulphur. Current findings are supported by Kumar and Yadav (2007) and Patil *et al.* (2018). It was found that sulphur is vital for protein synthesis in plants being a part of various amino acids. Our results are also in close proximity with Jat and Mehra (2007), Kumar and Yadav (2007) and Rajput *et al.* (2018).

Boost in calcium uptake by shoots after gypsum application

Results showed that all the treatments of gypsum except T_1 exhibited significant differences ($p < 0.05$) in calcium uptake in groundnut compared with control. Among all treatments significantly higher increase in Ca uptake by shoots was recorded when 50 % of the dose of gypsum was applied at the time of sowing and remaining 50 % of gypsum at flowering stage i.e., T_3 (Table 2). The overall increase in Ca uptake was in

order of $T_3 > T_4 > T_2 > T_5 > T_1$. The higher uptake of Ca is subjected to optimum amount of gypsum. Findings of Gashti *et al.*, (2012) are backing our results, they too reported increase in Ca uptake by application of gypsum.

Lift in phosphorus contents after gypsum application

Significant boost was observed in phosphorus contents of shoots and roots after higher dose of gypsum over control (Table 2). Application of 100 kg/ha at the time of sowing and 400kg/ha at flowering stage recorded remarkably maximum phosphorus content both in roots and shoots compared with other treatments and control one (Table 2). Highest phosphorus contents in shoot were recorded in T_4 , 75 % gypsum applied during sowing and 25 % gypsum applied during sprouting (Figure 1). The increase might be due to favourable effect of the high level of sulphur and calcium. Sulphur might have shown the synergistic effect in increasing the phosphorus uptake (Ismail *et al.*, 2013; Patel and Zinzala, 2018).

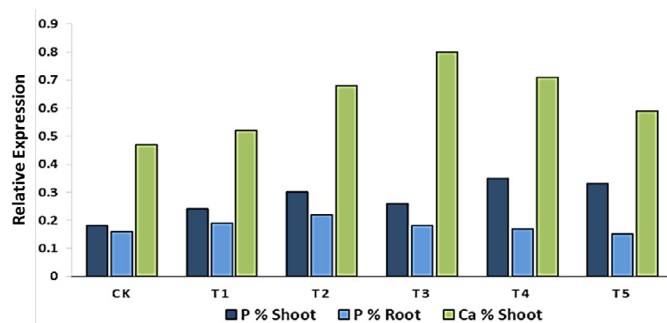


Figure 1: Phosphorus in shoots and roots and calcium in shoots under different levels of gypsum compared to control.

Effect of gypsum application on shelling percentage

Shelling percentage is one of the most critical features related to flowering pattern, development of kernels, and thickness of shell during the plant growth. The entire yield of groundnut depends on kernels, where nutrition management particularly calcium, distribution of rainfall, and genotype are the elements effecting it directly or indirectly (Gashti *et al.*, 2012). Our findings showed that application of gypsum significantly increased ($P < 0.05$) the shelling percentage (Table 2). Gypsum is highly soluble in the soil causing easily release and accessibility of calcium content around the pods, where pods can easily use and absorption calcium. Furthermore, gypsum prevents leaching down of other important nutrients as well as help in increase absorption of sulphur and phosphorus that can aid in increase yield of groundnut. The highest shelling percentage obtained

Table 1: Various morphometric traits estimated after gypsum application in different treatments.

Treatments	RFW	SFW	L/P	N/P	RD W (unit)	SDW (unit)	Shelling %
CK	3.33± 0.120 ^c	89.7±6.84 ^b	285.33±14.83 ^c	156± 2.081 ^d	1.05± 0.04 ^b	22.67±2.61 ^b	63.2±1.2 ^a
T1	4.22±0.473 ^{bc}	93.35±3.28 ^b	323.33±7.88 ^c	187± 4.72 ^c	1.91±0.20 ^{ab}	24.25±1.47 ^b	65.3±1.7 ^{ab}
T2	4.9±0.477 ^b	96.81±6.38 ^b	582±15.36 ^b	249±9.29 ^b	1.87±0.29 ^{ab}	24.97± 1.92 ^b	66±0.9 ^c
T3	9.03±0.486 ^a	261.26±2.59 ^a	764.67±12.99 ^a	382± 6.42 ^a	2.48± 0.70 ^a	59.78± 6.89 ^a	67±2.1 ^{cd}
T4	4.37± 0.255 ^{bc}	118.51±3.24 ^b	323.33±17.52 ^c	164.33±20.25 ^{cd}	1.66±0.16 ^{ab}	28.23±5.32 ^b	66.7±1.8 ^{cd}
T5	4.87± 0.791 ^b	118.33±7.75 ^b	279.67±7.31 ^c	114.67± 4.37 ^c	1.91± 0.45 ^{ab}	33.19±7.36 ^b	63.4±1.3 ^a

CK: Control (T0); RFW: Root fresh weight; SFW: shoot fresh weight; L/P: number of Leaves/plant; N/P: number of nodules/plant; RD W: root dry weight; SDW: stem dry weight; and shelling %. Values are the mean ± SEM of 12 values. Means sharing similar letter in a column are non-significant (P>0.05).

Table 2: Discrepancies in nutrient contents and morphometric traits after gypsum application.

Treat-ment	P % shoot	P % root	Ca % shoot	Root length (cm)	Shoot length (cm)	20 Pod length (cm)	Dry pod yield (g)	100 Kernels weight (g)
CK	0.18± 0.004 ^d	0.16±0.003 ^d	0.47±0.008 ^d	13.67±0.33 ^b	38.66±1.20 ^{ab}	60.66±0.33 ^b	2422.2±11.53 ^c	74.67±0.33 ^b
T1	0.24± 0.001 ^c	0.19±0.002 ^b	0.52±0.017 ^d	15.33±1.20 ^b	42.66±0.33 ^{ab}	60.33±0.33 ^b	3027.8±117.37 ^b	75.33±2.40 ^b
T2	0.3± 0.011 ^b	0.22± 0.005 ^a	0.68±0.025 ^b	15.00±0.57 ^b	37.00±1.15 ^b	61.33±0.88 ^b	3487.0±86.14 ^c	79.67±0.88 ^a
T3	0.26± 0.008 ^c	0.18±0.001 ^c	0.8±0.014 ^a	18.33±0.33 ^a	43.66±4.25 ^a	63.66±0.66 ^a	3522.2±131.97 ^a	76.67±1.20 ^{ab}
T4	0.35± 0.013 ^a	0.17±0.002 ^{cd}	0.71±0.021 ^b	15.17±1.09 ^b	39.66±1.45 ^{ab}	61.66±0.33 ^b	3253.7±92.75 ^{ab}	75.33±0.88 ^b
T5	0.33±0.009 ^{ab}	0.15± 0.004 ^c	0.59±0.031 ^c	14.83±1.30 ^b	39.00±1.52 ^{ab}	60.66±0.88 ^b	3140.8±59.60 ^b	75.33±1.20 ^b

CK: Control (T0); P % shoot: Phosphorus percentage in shoots; P % root: Phosphorus percentage in roots; Ca % shoot: Calcium percentage in shoots. Values are the mean ± SEM of 12 values. Means sharing similar letter in a column are non-significant (P>0.05).

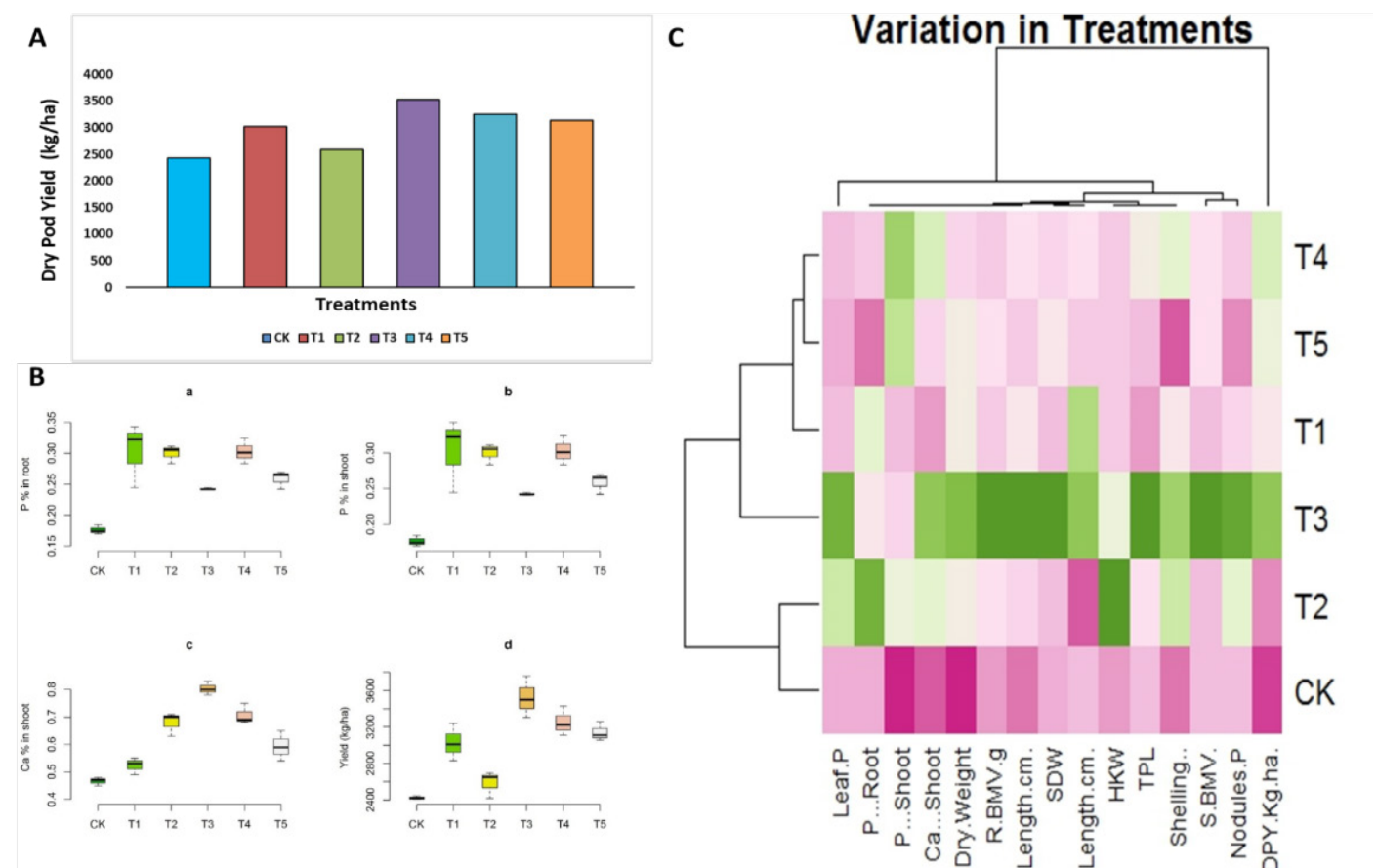


Figure 2: (A) Dry pod yield under different levels of gypsum. (B) Performance of control and treatments for a) P content (%) in root, b) P content (%) in shoot, c) Ca content (%) in shoot and d) grain yield (kg/ha) in response to gypsum application. (C) Effect of gypsum application showing extent of variation between control and treatments for morphometric traits, P content (%) in shoots and roots and Ca (%) in shoots.

from application of gypsum both at the time of sowing and sprouting (T_2 , T_3 and T_4) as compared to the addition of all gypsum either at sowing or sprouting time (Table 2). This may be due to increase in kernel weight in these treatments as both kernel weight and shelling percentage has a good positive relationship. Application of gypsum to large-seed cultivars is an effective technique in enrichment of kernels size and seed quality, because calcium contents released from gypsum is extra soluble in water (in contrast with other sources of calcium) and pods of groundnut plant can easily absorb it (Gashti *et al.*, 2012).

Positive contribution of gypsum in dry pod length and yield of groundnut

Appropriate nutrient management of crops is critical to improve the yield. Dry pod yield was significantly diverse among treatments ($p < 0.05$) in current study (Table 2). Results showed that only 250kg/ha of gypsum at sowing time and 250kg/ha at the sprouting time (T_3) produced longer pods as compared to other treatments and control. It was also noted that use of calcium and sulphur (gypsum) had highly significant effect on yield (Table 2). Among all treatments of gypsum significantly improved yield was documented when gypsum was applied both at sowing and sprouting stages as compared to control (Figure 2A, 2B and 2C). However, maximum yield was recorded after application of 250kg/ha of gypsum at the time of sowing and 250kg/ha at the sprouting time (T_3). Studies confirmed that groundnut yield increased with fertilizer application including calcium and sulfur i.e., single super phosphate, ammonium sulfate in the alkali soils and gypsum (Macció *et al.*, 2002; Gashti *et al.*, 2012). According to Wiatrak *et al.* (2006) gypsum application aided to increase yield of groundnut with high potential yield by accumulative availability of Ca in the fruiting zone in strip-till management systems. They further clarified that yield of groundnut was higher after application of gypsum in comparison to plants without gypsum application. Increased crop productions by application of gypsum have also been reported in studies by Fernandes *et al.* (2007) and Rasouli *et al.* (2013).

Gypsum application results in increased 100 kernels weight

The trait of 100 kernels weight is an important one to estimate the crop yield. In groundnut it is directly related to the accessibility of crop to optimum amount of nutrients at proper growth stage (Kost *et al.*, 2014). Fluctuations in the availability of essential

elements mainly sulphur and calcium around the pods significantly affects the kernels weight (Sushila, 1992; Adams *et al.*, 1993). However, in this study gypsum application had little effect on 100 kernels weight (Table 2). Calcium present in the gypsum may lead to the production of big kernels through speedup of relative growth rate (RGR) of pods or enhance the production of photosynthetic materials which as result increase its transportation towards growing kernels. Highest 100 kernels weight attained when 25 % of gypsum at the sowing time and remaining 75 % at the flowering time (T_2) was applied compared to others treatments and control (Table 2). Many studies have showed that quality and size of kernels in groundnut increased by the addition of elements like sulphur and calcium (Gashti *et al.*, 2012). Gypsum being a good source of sulphur and calcium for pods in groundnut and should be applied at proper time in optimum amount to get qualitative and bigger kernels.

Conclusions and Recommendations

The application of gypsum overall improves the fresh and dry weight as well as plant height leading to yield increase in terms of better shelling percentage, pods length and productivity, and kernel weight under normal soil conditions. Application of gypsum either at sowing or flowering time alone did not produce fruitful results. However, split dose of gypsum gave much impressive results. Among all split treatments T_3 i.e., 50 % of gypsum at sowing time and 50 % at flowering time affectedly increased all available parameters. We recommend T_3 dose of gypsum to increase the agronomic efficiency of groundnut under normal soil conditions.

Acknowledgments

The authors acknowledge the contribution of Land Resources Research Institute, National Agricultural Research Centre, Islamabad for providing technical support in terms of experimental design and nutrient analysis.

Novelty Statement

The optimum doses of gypsum i.e. 50 % at sowing time and 50 % at flowering time significantly increase grain yield and mineral concentration.

Author's Contribution

MJ, NN and MA: Plan, supervised, carried out the experiment, and wrote the manuscript.

MS, MH and SS: Assisted in field layout.

HK and SAK: Helped in statistical analysis, figures drawing, and revision of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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