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# Differential Response of Groundnut Genotypes for Varying $CaCO_3$ Concentrations

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## ABSTRACT

**Background:** Soil calcareousness is the major problem in arid and semi arid regions globally since lime induced chlorosis lead to the deficiency of many essential plant nutrients which in turn resulted in reduced growth and yield loss of many crops. To explore the effects of various concentrations of calcium carbonate ($CaCO_3$) on seed germination and seedling growth of groundnut genotypes and to identify $CaCO_3$ stress tolerant and sensitive groundnut genotypes.

**Methods:** The seed germination and seedling growth of ten groundnut genotypes (CO 6, CO 7, TMV 2, TMV 10, TMV 13, TMV 14, VRI 7, VRI 8, ALR 2 and BSR 2) was investigated with $CaCO_3$ concentrations ranging from 1 to 100 mM $L^{-1}$ for a period of 14 days.

**Result:** The genotypes VRI 8 and TMV 10 showed higher seed germination and seedling growth even at higher $CaCO_3$ concentration (upto 20 mM $L^{-1}$) and considered as tolerant genotypes. Whereas TMV 2 and VRI 7 exhibited drastic reduction even at 1 mM $L^{-1}$ and confirms their susceptibility to $CaCO_3$ stress. Higher concentrations of $CaCO_3$ in the growing medium greatly decreased the germination rate, germination index and vitality index but the impact differs with potentials of genotypes studied.

**Key words:** Calcium carbonate, Groundnut genotypes, Seed germination, Seedling growth, Vigour, Vitality indices.

## INTRODUCTION

Groundnut (*Arachis hypogaea* L.) serves as the world's largest source of edible oil, ranks 4th among oilseed crops (Yadav *et al*., 2017) and it continues to be a predominant crop in India since it is the major source of dietary oil (42-52%), protein (25-30%) and an important cash crop for both subsistence and urban dwellers (Manaf *et al*., 2017). It is grown worldwide at 28.51 million ha and in India it is grown in 4.88 m ha (INDIASTAT 2017-18). About 70% of the world groundnut cultivation occurs in the semi-arid tropics where soils are mostly calcareous and alkaline (Manasa *et al.,* 2020). Though groundnut is severely affected by the presence of $CO_3^-$ and $HCO_3^-$ ions in the calcareous soils, the seed germination and their tolerance mechanism will vary from crop to crop based on their genetic potentials. The important selection criterion for screening $CaCO_3$ tolerance in many species is the vigorous growth at seedling stage (Ali *et al.,* 2021). Since groundnut grown in calcareous soils commonly affected by lime induced chlorosis at early growth periods, knowledge on the tolerance of groundnut varieties for varying intensities of soil calcareousness is very much essential.

Calcareous soils are common in arid and semiarid climates, and occur as inclusions in more humid areas. About 228.8 m ha (69.4%) of total area in India and 3.70 m ha (28.4%) of total area in Tamil Nadu (www.gis.nic.in). More than one third of the soils in India are calcareous and present in the low rainfall areas of Karnataka, Gujarat, Maharashtra, Rajasthan, Madhya Pradesh and Uttar Pradesh where groundnut (*Arachis hypogaea* L.) is grown as a major crop (Omesh Kumar *et al.,* 2019). These soils generally possess less plant nutrients (Mann *et al.,* 2017), high bases, bicarbonate and calcium content with the pH of 7.50 to 8.50 (Motesharezadeh *et al.,* 2017). The carbonate, bicarbonate and calcium ions in the calcareous soils have an inhibitory effect on germination and seedling growth parameters. Higher pH, prolonged elevated carbonate and $Ca^{2+}$ ions may also pose stress to seed germination (Muscolo *et al.,* 2007) and seedling development. The high pH of calcareous soil affects the enzymes involved in seed germination which leads to reduced crop establishment (Mansouri *et al.,* 2019). Higher concentration of bicarbonate ions and pH of the calcareous soils reduces the utilization of essential plant nutrients by the plants (Cirka *et al.,* 2021). Hence higher concentration of $CaCO_3$ limits the resumption of seed metabolic activity (Moghaddam *et al.,* 2018) and such information is important to understand the strategies for higher seed germination and seedling establishment.

Perusal of various literatures pertaining to the tolerance of groundnut genotypes to soil calcareousness is scanty hence detailed study on the genotypic variability for $CaCO_3$ stress is warranted. Therefore, the present study was carried out to evaluate the tolerance levels of different groundnut

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genotypes with varying intensities of $CaCO_3$ concentrations on seed germination and seedling growth.

## MATERIALS AND METHODS

### Experimental materials

Seeds of ten groundnut genotypes *viz.*, CO 6, CO 7, TMV 2, TMV 10, TMV 13, TMV 14, VRI 7, VRI 8, ALR 2 and BSR 2 were collected from the Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore and used for the study. Eight different $CaCO_3$ concentrations (0, 1, 5, 10, 15, 20, 25, 50 and 100 mM $L^{-1}$) were prepared from the stock solution (200 mM $L^{-1}$) using analar grade $CaCO_3$ powder in a factorial completely randomized block design. Nine seeds from each groundnut genotype were placed in portrays and incubated with 0 (Distilled water), 1, 5, 10, 15, 20, 25, 50 and 100 mM $L^{-1}$ of $CaCO_3$ concentrations and grown for a period of 14 days in a controlled laboratory conditions. The experiment was conducted at the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore during 2020.

### Seed germination

Nine uniform sized seeds of all the groundnut genotypes were selected rinsed with distilled water, shade dried and placed in portrays individually and grown. Ten mL of the double distilled water as control and different concentrations of $CaCO_3$ was added to portray. The experiment was performed in completely randomised block design with three replications. All portrays were maintained at room temperature (25°C) throughout the experiment and harvested after 14 days. The solutions were replenished every day and continued until the expiry of test period.

From second day, the number of seeds germinated was counted and continued up to 14 days (336 h). The germination percentage (GP) (Nicols and Heydecker, 1968), germination rate (GR) (Maghsoudi and Arvin, 2010) and germination Index (GI) (Association of Official Seed Analysis (AOSA), 1983) and germinative energy were computed for evaluating the tolerance and sensitivity of groundnut genotype for $CaCO_3$ stress. The formulas used for computing the various indices were as follows:

Germination per cent (%) =

$$\frac{\text{Total number of all germinated seeds}}{\text{Total number of tested seeds}} \times 100 \quad (1)$$

Germination rate (GR %) =

$$\frac{\text{No. of seeds germinated within three days}}{\text{No. of seeds germinated after 14 days}} \times 100 \quad (2)$$

Germination index =

$$\frac{\text{No. of seeds germinated during time t}}{\text{Number of germination days}} \quad (3)$$

### Seedling growth

The seeds with extruded plumule and radical length of > 2 mm were considered as a seedling. The seedling growth parameters like root length, shoot length and total seedling length were recorded after 14 days of incubation. The shoot length was measured from the base of primary leaf to the base of hypocotyls and root length was measured from primary root tip to hypocotyls' base and the units were expressed in centimeter (cm).

To measure the fresh weight, fresh seedlings were weighed and the seedlings were dried in a hot air oven at 70°C until achieving constant weight and then weighed for recording the dry weight. Using the data, the inhibition rate (%), vitality index and vigour index I and II were computed as below:

Inhibition rate (%) =

$$\frac{\text{Root length at control - Root length at stress}}{\text{Number of germinated days}} \times 100$$

Vitality index = Seedling root lenght X Σ

$$\frac{\text{No. of seeds germinated during time t}}{\text{Number of germination days}}$$

### Statistical analysis

Data recorded during the course of investigations was analysed statistically using Agress software (Snedecor and Cochran, 1967). The significant differences between the treatments and the mean comparisons were made using Fisher's least significant difference (LSD) test at P=0.05. Critical difference was computed to compare the treatment means and correlation studies were made to understand the relationship between various parameters.

## RESULTS AND DISCUSSION

### Germinability of seeds

The presence of $CaCO_3$ in the growing medium reduced the seed germination and establishment significantly when it reaches excessive concentration of $CaCO_3$ (Fig 1). Beyond 15 mM $CaCO_3$ $L^{-1}$, seed germination of all the genotypes was highly affected and the least values were noted at 100 mM $CaCO_3$ $L^{-1}$. VRI 8 showed 100% germination upto 20 mM $CaCO_3$ $L^{-1}$ and even at 100 mM $CaCO_3$ $L^{-1}$ it showed 50% germination, followed by TMV 10, which showed 100% germination upto 15 mM $CaCO_3$ $L^{-1}$. Whereas, TMV 2 and VRI 7 recorded only 11% germination at the same $CaCO_3$ concentration indicating their sensitiveness to $CaCO_3$ stress. This reduction in germination as a result of increased $CaCO_3$ concentration, might be due to reduced seed water imbibitions, excess toxic ions, nutrient imbalances in seed embryo and osmotic potential (Abbasian and Moemeni, 2013; Moghaddam *et al.,* 2018).

Compared to control, effect of $CaCO_3$ on the germination rate was marked and the magnitude of reduction was higher at 100 mM $CaCO_3$ $L^{-1}$ (Fig 2). VRI 8 showed higher GR at all

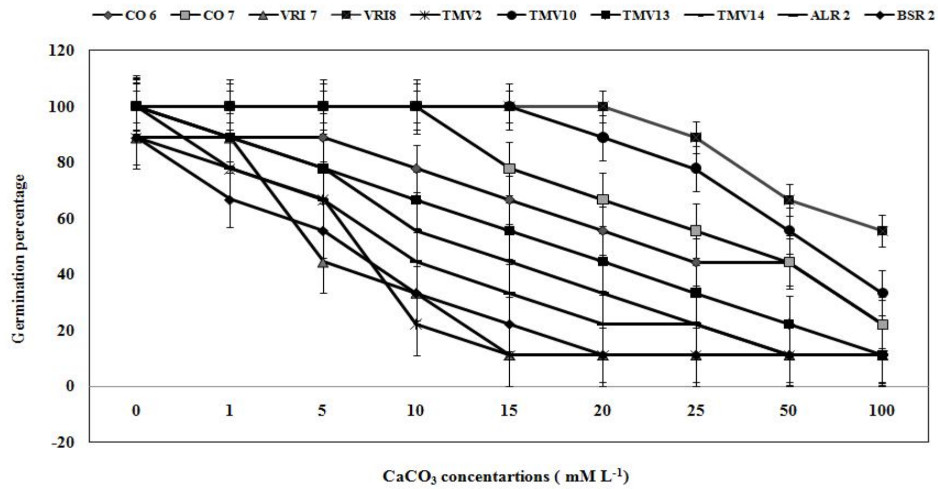


**Fig 1:** Effect of different $CaCO_3$ concentration on the germination percentage of groundnut genotypes.

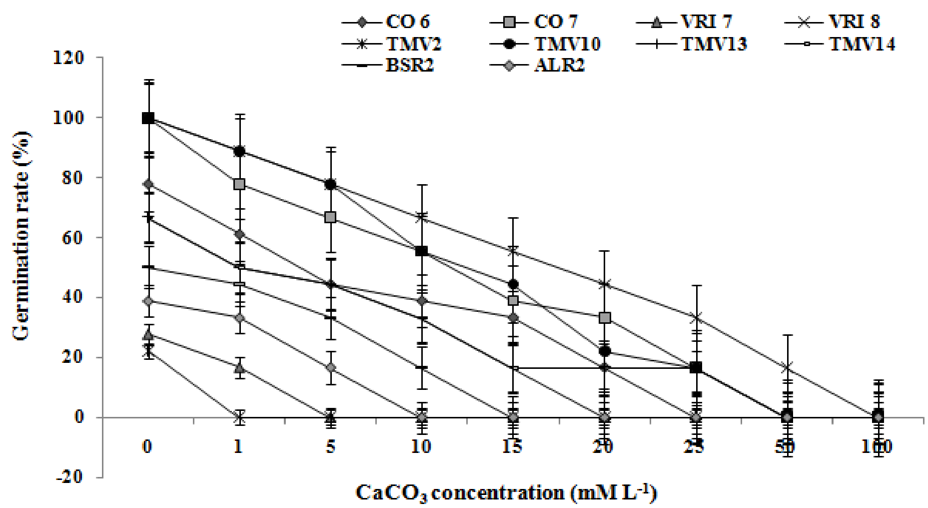


**Fig 2:** Effect of different $CaCO_3$ concentration on the germination rate of groundnut genotypes.

tested $CaCO_3$ concentrations except 100 mM $L^{-1}$ $CaCO_3$ concentration, where the seeds did not germinate after 3 days of incubation (DAI). In case of TMV 10, upto 50 mM $CaCO_3$ $L^{-1}$ concentration, the seeds germinated 3 days after incubation. The most sensitive TMV 2 showed poor germination rate starting from 1 mM $CaCO_3$ $L^{-1}$ concentration. The main reason for the reduction in the germination rate is the toxic effects of $CO_3^-$ and $HCO_3^-$ ions which hinders the water absorption, metabolic and physiological processes of seeds as a result the germination process is delayed. The results were in confirmation with the findings reported by Leblebici and Isık, (2018), Kołodziejek and Patykowsk (2015) in Galium cracoviense seeds and Gadwal and Naik (2014) in Hibiscus species.

Germination index (GI) showed significant reduction in all the genotypes irrespective of $CaCO_3$ concentrations (Table 1). The inhibitory effect was obvious from 10 mM $CaCO_3$ $L^{-1}$ and the maximum reduction was observed at 100 mM $CaCO_3$ $L^{-1}$. Minimum inhibitory effect and growth reduction was noted with the genotype VRI 8 (1.68 to 5.25), TMV 10 (1.05 to 5.25) and CO 7 (0.95 to 4.67). The maximum inhibitory effect was exhibited as lesser germination index in TMV 2 (0.14 to 2.55) and VRI 7 (0.22 to 2.70). The inhibitory effect on germination index was obvious from 5 mM $CaCO_3$ $L^{-1}$ and the maximum reduction was observed at 100 mM $CaCO_3$ $L^{-1}$. This could be ascribed to the higher concentration of exogenous $HCO_3^-$ and $CO^{3-}$ ions (Cai *et al.,* 2013; Kołodziejek and Patykowsk, 2015).

### Seedling growth

Shoot length of seedlings decreased significantly with increasing concentration of $CaCO_3$ with the overall mean shoot length of 3.23 to 8.20 cm (Table 2). Maximum reductions in the shoot growth was recorded at 100 mM $CaCO_3$ $L^{-1}$ concentration, but their magnitude of reduction varied with genotypes. Lesser reduction in the shoot length was observed with VRI 8 (4.64 to 9.26 cm) followed by TMV 10 (4.40 to 9.22 cm). The highest reduction in shoot length was witnessed in TMV 2 (1.75 to 6.13 cm) and VRI 7 (2.16 to 6.69 cm) form 1 mM $CaCO_3$ $L^{-1}$ and reached the maximum at 100 mM $CaCO_3$ $L^{-1}$.

In case of root length also VRI 8(4.70 to 9.24 cm) performed well with lesser reduction in root growth, followed by TMV 10 (4.05 to 8.73 cm) and CO 7 (3.74 to 8.51 cm) (Table 3). The genotype TMV 2 (0.96 to 4.40 cm) and VRI 7 (1.19 to 5.05 cm) showed poor root length which showed their sensitivity to calcareousness. Similar results were reported by Wehr *et al.* (2016) in *Leucaena* and *Rhodes grass* and by Helper, (2010) in barley. The reduced seedling root growth might be attributed to higher growing media pH, $Ca^{2+}$, $CO_3^-$ and $HCO_3^-$ concentration which affected the root growth and development by disturbing the seed hydration, Photosynthetic rate (Ding *et al.,* 2019) and toxicity (Moghaddam *et al.,* 2018).

The reduction in biomass was minimum with VRI 8 (1.86 g) followed by TMV 10 (1.69 g) and CO7 (1.26 g) (Fig 3). The genotype TMV 2 (0.18 g) showed greater reduction in dry biomass followed by VRI 7(0.19 g) at 100 mM $CaCO_3$ $L^{-1}$. About 50% reduction was noticed at a concentration of 20 mM $L^{-1}$ in these varieties. The drastic reduction at higher concentration might be due to increased metabolic energy and reduced carbon gain which might have led to reduced biomass production. On the other hand, suppression of water absorption and resumption of seed metabolic activity was also affected thus resulted in poor germination and seedling establishment (Pratap and Kumar Sharma, 2010; Jiao *et al.,* 2021).

### Vitality index

The vitality index decreased exponentially with increasing $CaCO_3$ concentration and reaches zero when the concentration

**Table 1:** Effect of various concentrations of $CaCO_3$ on the germination index of groundnut genotypes.

| Concentrations of $CaCO_3$ (mM $L^{-1}$) | Groundnut genotypes | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO 6 | CO 7 | VRI7 | VRI8 | TMV2 | TMV10 | TMV13 | TMV14 | BSR2 | ALR2 | |
| 0 | 4.30$^{ad}$ | 4.67$^{ac}$ | 2.70$^{agh}$ | 5.25$^{a}$ | 2.55$^{ah}$ | 5.25$^{ab}$ | 4.21$^{ade}$ | 3.88$^{aef}$ | 3.28$^{agh}$ | 3.35$^{afg}$ | 3.95 |
| 1 | 3.81$^{bd}$ | 4.50$^{bc}$ | 2.44$^{bgh}$ | 5.06$^{ab}$ | 1.81$^{bh}$ | 4.89$^{b}$ | 3.63$^{bde}$ | 3.30$^{bef}$ | 2.27$^{bgh}$ | 2.80$^{bfg}$ | 3.45 |
| 5 | 3.35$^{cd}$ | 4.38$^{c}$ | 1.34$^{cgh}$ | 4.95$^{ac}$ | 1.30$^{ch}$ | 4.74$^{bc}$ | 2.87$^{cde}$ | 2.83$^{cef}$ | 1.45$^{cgh}$ | 2.12$^{cfg}$ | 2.93 |
| 10 | 2.76$^{d}$ | 4.32$^{cd}$ | 0.80$^{dgh}$ | 4.84$^{ad}$ | 0.78$^{dh}$ | 4.58$^{bd}$ | 2.21$^{de}$ | 1.85$^{def}$ | 0.91$^{dgh}$ | 1.28$^{dfg}$ | 2.43 |
| 15 | 1.78$^{de}$ | 2.83$^{ce}$ | 0.47$^{egh}$ | 4.37$^{ae}$ | 0.32$^{eh}$ | 4.25$^{be}$ | 1.58$^{de}$ | 1.30$^{ef}$ | 0.71$^{egh}$ | 0.80$^{efg}$ | 1.84 |
| 20 | 1.30$^{df}$ | 2.10$^{cf}$ | 0.39$^{fgh}$ | 4.16$^{af}$ | 0.27$^{fh}$ | 3.33$^{bf}$ | 1.12$^{def}$ | 0.75$^{ef}$ | 0.47$^{fgh}$ | 0.74$^{fg}$ | 1.46 |
| 25 | 1.29$^{dfg}$ | 1.82$^{cfg}$ | 0.32$^{fgh}$ | 3.61$^{afg}$ | 0.22$^{fgh}$ | 3.01$^{bfg}$ | 0.75$^{defg}$ | 0.59$^{efg}$ | 0.32$^{fgh}$ | 0.44$^{fg}$ | 1.24 |
| 50 | 0.97$^{dgh}$ | 1.57$^{cgh}$ | 0.27$^{gh}$ | 2.51$^{agh}$ | 0.18$^{gh}$ | 1.66$^{bgh}$ | 0.80$^{degh}$ | 0.47$^{efgh}$ | 0.22$^{gh}$ | 0.27$^{fgh}$ | 0.89 |
| 100 | 0.18$^{dh}$ | 0.95$^{ch}$ | 0.22$^{gh}$ | 1.68$^{ah}$ | 0.14$^{h}$ | 1.05$^{bh}$ | 0.47$^{deh}$ | 0.32$^{efh}$ | 0.18$^{gh}$ | 0.22$^{fgh}$ | 0.54 |
| Mean | 1.72 | 2.49 | 0.69 | 3.46 | 0.56 | 3.06 | 1.49 | 1.27 | 0.96 | 0.73 | 1.64 |
| | G | C | | G × C | | | | | | | |
| SEd | 0.20 | 0.18 | | 0.59 | | | | | | | |
| CD (P=0.05) | 0.39 | 0.37 | | 1.18 | | | | | | | |

*G- Genotypes; C - Concentrations.

*Values within a column followed by different letters are significantly different at the 0.05 probability level.

**Table 2:** Effect of various concentrations of $CaCO_3$ on the shoot length of groundnut genotypes.

| Concentrations of $CaCO_3$ (mM $L^{-1}$) | Groundnut genotypes | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO 6 | CO 7 | VRI7 | VRI8 | TMV2 | TMV10 | TMV13 | TMV14 | BSR2 | ALR2 | |
| 0 | 8.64$^{ac}$ | 9.14$^{ab}$ | 6.96$^{ah}$ | 9.26$^{a}$ | 6.13$^{ai}$ | 9.22$^{ab}$ | 8.43$^{ad}$ | 8.29$^{ae}$ | 7.81$^{ag}$ | 8.13$^{af}$ | 8.20 |
| 1 | 8.37$^{bc}$ | 8.89$^{b}$ | 6.64$^{bh}$ | 9.10$^{ab}$ | 5.83$^{bi}$ | 9.00$^{b}$ | 8.16$^{bd}$ | 8.01$^{be}$ | 7.48$^{bg}$ | 7.83$^{bf}$ | 7.93 |
| 5 | 8.23$^{c}$ | 8.76$^{bc}$ | 5.66$^{ch}$ | 8.93$^{ac}$ | 4.79$^{ci}$ | 8.85$^{bc}$ | 7.25$^{cd}$ | 7.07$^{ce}$ | 6.61$^{cg}$ | 6.91$^{cf}$ | 7.31 |
| 10 | 7.35$^{cd}$ | 7.95$^{bd}$ | 5.07$^{dh}$ | 8.16$^{ad}$ | 3.97$^{di}$ | 8.04$^{bd}$ | 6.90$^{d}$ | 6.24$^{de}$ | 5.73$^{dg}$ | 6.10$^{df}$ | 6.55 |
| 15 | 6.94$^{ce}$ | 7.41$^{be}$ | 4.24$^{eh}$ | 7.81$^{ae}$ | 3.68$^{ei}$ | 7.64$^{be}$ | 6.23$^{de}$ | 6.04$^{e}$ | 4.84$^{eg}$ | 5.68$^{ef}$ | 6.05 |
| 20 | 6.11$^{cf}$ | 6.54$^{bf}$ | 3.73$^{fh}$ | 7.27$^{af}$ | 3.17$^{fi}$ | 6.74$^{bf}$ | 5.39$^{df}$ | 5.24$^{ef}$ | 4.49$^{fg}$ | 5.01$^{f}$ | 5.37 |
| 25 | 5.26$^{cg}$ | 5.73$^{bg}$ | 3.33$^{gh}$ | 6.60$^{ag}$ | 2.87$^{gi}$ | 5.90$^{bg}$ | 5.07$^{dg}$ | 4.84$^{eg}$ | 3.89$^{g}$ | 4.26$^{fg}$ | 4.77 |
| 50 | 4.31$^{ch}$ | 4.70$^{bh}$ | 2.58$^{h}$ | 5.81$^{ah}$ | 2.18$^{hi}$ | 5.00$^{bh}$ | 4.07$^{dh}$ | 3.81$^{eh}$ | 3.05$^{gh}$ | 3.53$^{fh}$ | 3.90 |
| 100 | 3.59$^{ci}$ | 4.08$^{bi}$ | 2.16$^{hi}$ | 4.64$^{ai}$ | 1.75$^{i}$ | 4.40$^{bi}$ | 3.48$^{di}$ | 2.96$^{ei}$ | 2.72$^{gi}$ | 2.56$^{fi}$ | 3.23 |
| Mean | 6.53 | 7.02 | 4.48 | 7.51 | 3.82 | 7.20 | 6.11 | 5.83 | 5.56 | 5.18 | 5.92 |
| | G | C | | G × C | | | | | | | |
| SEd | 0.19 | 0.09 | | 0.29 | | | | | | | |
| CD (P=0.05) | 0.22 | 0.18 | | 0.58 | | | | | | | |

*G- Genotypes C - Concentrations.

*Values within a column followed by different letters are significantly different at the 0.05 probability level.

**Table 3:** Effect of various concentrations of $CaCO_3$ on the root length of groundnut genotypes.

| Concentrations of $CaCO_3$ (mM $L^{-1}$) | Groundnut genotypes | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CO 6 | CO 7 | VRI7 | VRI8 | TMV2 | TMV10 | TMV13 | TMV14 | BSR2 | ALR2 | |
| 0 | 7.76$^{ad}$ | 8.51$^{ac}$ | 5.05$^{ai}$ | 9.24$^{a}$ | 4.40$^{aj}$ | 8.73$^{ab}$ | 6.73$^{ae}$ | 6.44$^{af}$ | 5.66$^{ah}$ | 5.95$^{ag}$ | 6.85 |
| 1 | 7.56$^{bd}$ | 8.32$^{bc}$ | 4.82$^{bi}$ | 9.09$^{ab}$ | 4.20$^{bj}$ | 8.55$^{b}$ | 6.50$^{be}$ | 6.21$^{bf}$ | 5.42$^{bh}$ | 5.72$^{bg}$ | 6.64 |
| 5 | 7.38$^{cd}$ | 8.13$^{c}$ | 4.14$^{ci}$ | 8.89$^{ac}$ | 3.47$^{cj}$ | 8.38$^{bc}$ | 6.07$^{ce}$ | 5.58$^{cf}$ | 4.79$^{ch}$ | 5.08$^{cg}$ | 6.19 |
| 10 | 6.62$^{d}$ | 7.29$^{cd}$ | 3.95$^{di}$ | 8.07$^{ad}$ | 2.90$^{dj}$ | 7.54$^{bd}$ | 5.11$^{de}$ | 5.02$^{df}$ | 4.78$^{dh}$ | 4.84$^{dg}$ | 5.61 |
| 15 | 5.97$^{de}$ | 6.59$^{ce}$ | 3.26$^{ei}$ | 7.41$^{ae}$ | 2.69$^{ej}$ | 6.81$^{be}$ | 4.79$^{e}$ | 4.32$^{ef}$ | 3.66$^{eh}$ | 3.92$^{eg}$ | 4.94 |
| 20 | 5.05$^{df}$ | 5.61$^{cf}$ | 2.84$^{fi}$ | 6.96$^{af}$ | 2.24$^{fj}$ | 6.02$^{bf}$ | 4.27$^{ef}$ | 3.99$^{f}$ | 3.24$^{fh}$ | 3.55$^{gf}$ | 4.38 |
| 25 | 4.66$^{dg}$ | 5.14$^{cg}$ | 2.13$^{ig}$ | 6.20$^{ag}$ | 1.77$^{gj}$ | 5.42$^{bg}$ | 4.05$^{eg}$ | 3.82$^{fg}$ | 2.71$^{gh}$ | 3.10$^{g}$ | 3.90 |
| 50 | 4.02$^{dh}$ | 4.44$^{ch}$ | 1.87$^{hi}$ | 5.13$^{ah}$ | 1.58$^{hj}$ | 4.78$^{bh}$ | 3.26$^{eh}$ | 3.04$^{fh}$ | 2.16$^{h}$ | 2.54$^{gh}$ | 3.28 |
| 100 | 3.39$^{di}$ | 3.74$^{ci}$ | 1.19$^{i}$ | 4.70$^{ai}$ | 0.96$^{ij}$ | 4.05$^{bi}$ | 2.66$^{ei}$ | 2.26$^{fi}$ | 1.69$^{hi}$ | 2.07$^{gi}$ | 2.67 |
| Mean | 5.82 | 6.42 | 3.25 | 7.30 | 2.69 | 6.70 | 4.83 | 4.52 | 4.08 | 3.79 | 4.94 |
| | G | C | | G × C | | | | | | | |
| SEd | 0.09 | 0.08 | | 0.27 | | | | | | | |
| CD (P=0.05) | 0.18 | 0.17 | | 0.54 | | | | | | | |

*G- Genotypes C - Concentrations.

*Values within a column followed by different letters are significantly different at the 0.05 probability level.

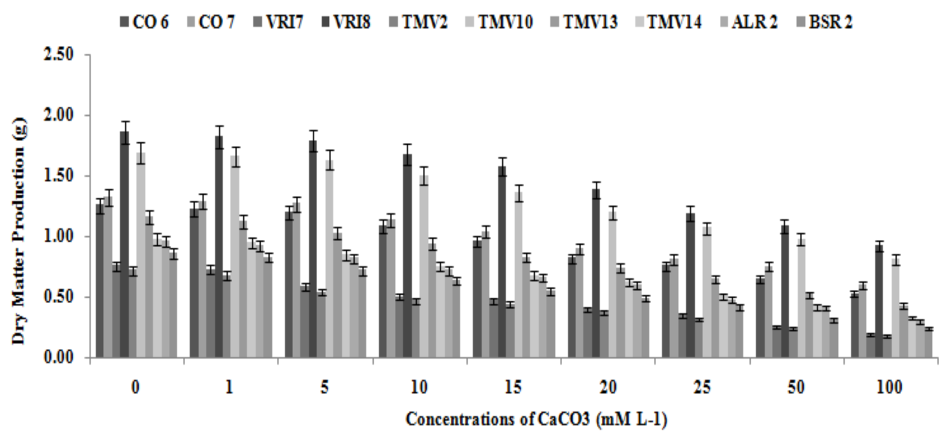


**Fig 3:** Effect of different $CaCO_3$ concentration on the germination rate of groundnut genotypes.

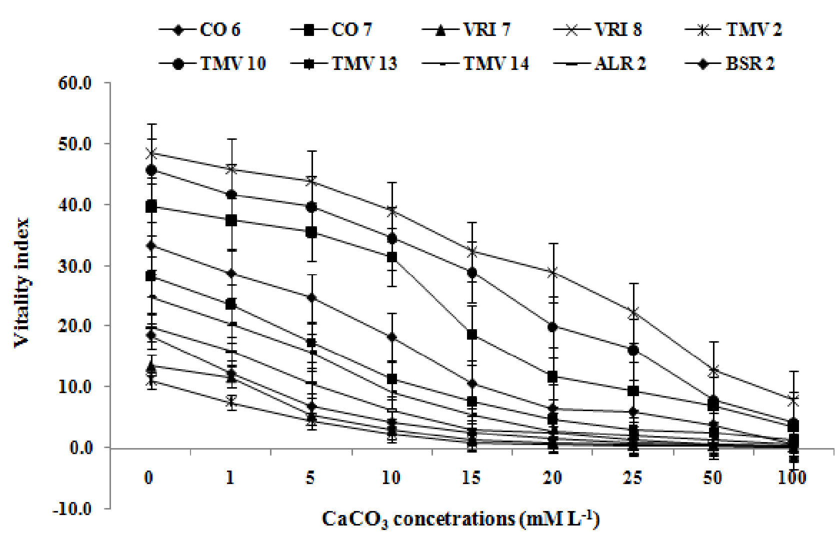


**Fig 4:** Effect of different $CaCO_3$ concentration on the vitality index of groundnut genotypes.

exceeds 15 mM $L^{-1}$ (Fig 4). Better vitality index was observed with VRI 8 at all the concentrations indicating its tolerance to $CaCO_3$ stress. But lesser vitality index was observed in TMV 2 indicating its sensitiveness to $CaCO_3$ stress (Kandila *et al*., 2012; Kaur and Gupta, 2018).

The $CaCO_3$ stress had marked inhibitory effect on the root elongation of the seedlings (Fig 5). The effect was visible even at lower concentration of 1 mM $CaCO_3$ $L^{-1}$ and it differs widely with genotypes. However the effect was greater when the $CaCO_3$ concentration exceeds 15 mM $CaCO_3$ $L^{-1}$. The genotype VRI 8 showed lesser inhibitory effect of $CaCO_3$ concentration on root elongation and the sensitive TMV 2 showed inhibition effect from 5 mM $CaCO_3$ $L^{-1}$.

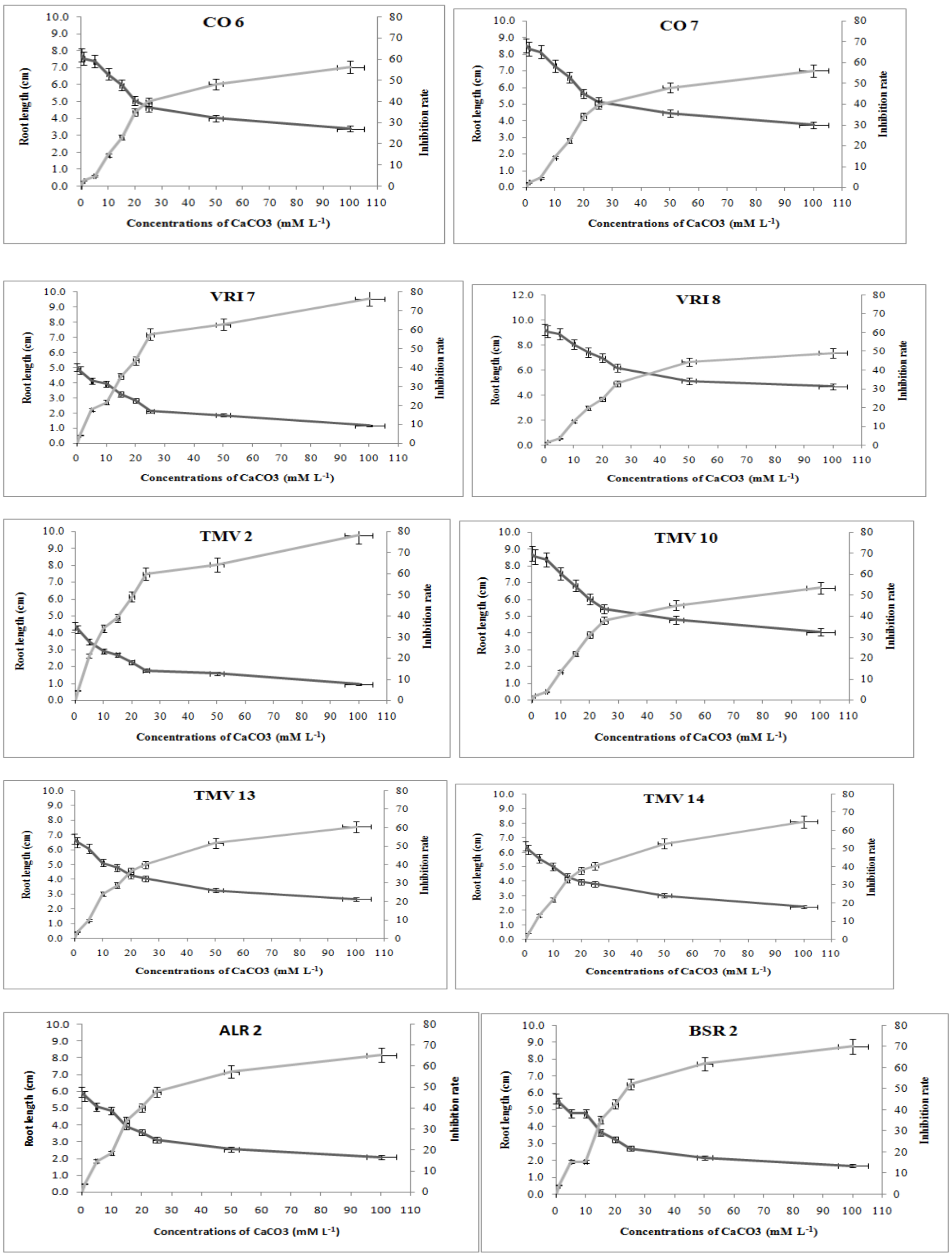


**Fig 5:** Effect of different $CaCO_3$ concentration on root elongation of groundnut genotypes.

## CONCLUSION

Understanding the sensitivity of crops to $CaCO_3$ stress at germination and seedling establishment stages is essential to avoid crop loss when grown on calcareous soils. In this context this study aims to screen various groundnut genotypes for different $CaCO_3$ concentrations so as to group them into tolerant and sensitive genotypes. The results showed greater reduction in seed germination and seedling growth parameters of groundnut genotypes with increasing $CaCO_3$ stress which was not the same among the genotypes. The varieties such as VRI 8, TMV 10 and CO 7 were grouped as tolerant genotypes registering higher seed germination and seedling establishment with lesser inhibitory effect of $CaCO_3$ concentrations. However, the genotypes TMV 2 and VRI 7 were found to be highly sensitive to $CaCO_3$ stress. Rest of the genotypes *viz.*, CO 6, TMV 13, TMV 14, BSR 2 and ALR 2 were moderately tolerant to calcareousness. Considerable reduction in seed germination and seedling growth was noted even after the concentration exceeds 15 mM $L^{-1}$ for tolerant genotypes indicating that $CaCO_3$ stress is the potential yield limiting factor in arid and semi arid regions. These findings may be highly useful to select the crops suitable for calcareous soils so as to avoid yield loss. Further the genetic differences may be exploited for developing new cultivars to be grown on calcareous soils to achieve better crop yield.

## ACKNOWLEDGEMENT

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