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Effect of low grade rock phosphate, single super phosphate and their mixtures on soil exchangeable calcium, Δ Ca in a groundnut-maize cropping system on the acid Alfisols of Odisha state, India over two years

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Abstract

To find out the effect of low grade Udaipur rock phosphate (URP), single super phosphate and their mixtures on exchangeable soil calcium at different growth stages of a groundnut- maize cropping system, a field experiment was conducted in a randomized block design with three replications and eight treatments from 2013-14 to 2015. The soil has a loam texture, a pH of 5.18, low available nitrogen and medium phosphorus and potassium. In control, exchangeable calcium decreased gradually from the initial value of 1.31 c mol (p⁺) kg⁻¹ to 0.74 c mol (p⁺) kg⁻¹ after four seasons. In sole URP treatments (T₂ and T₇) the exchangeable calcium in T₂ and T₇ after four seasons were 1.07 and 1.01 c mol (p⁺) kg⁻¹ respectively. The highest value of exchangeable calcium 1.18 c mol (p⁺) kg⁻¹ was recorded in SSP+ lime treatment (T₈) followed by 1.16 in SSP (T₃) and 1.15 c mol (p⁺) kg⁻¹ in URP+SSP 1:1 (T₅) treatments respectively. Maximum dissolution of URP in the root zone of maize-groundnut cropping system occurred during 30-60 DAS after sowing whereas higher dissolution of URP occurred within 30 DAS in URP+SSP (1:1) treatment.

Keywords: URP; exchangeable calcium; Δ Ca; groundnut-maize cropping system

Introduction

Experimental site

The effects of low grade Udaipur rock phosphate (URP), single super phosphate (SSP) and their combinations on changes in soil exchangeable calcium in different growth stages was studied in a groundnut-maize cropping system during two consecutive years (2013-2014 to 2015) through a field experiment. The experiment was conducted in the Central Farm, Odisha University of Agriculture and Technology. The site is at Bhubaneswar 85° 47' 18" E latitude 20° 16' 51" N longitudes with an elevation of 25.9 m above mean sea level. It is situated at about 64 km away from the Bay of Bengal within the East and South- Eastern Coastal Plain agro-climatic zone of Odisha and falls under the East Coastal Plains and Hills zone of the humid tropics of India. The climate is characterized as hot, moist and sub-humid with hot summers and mild winters. Broadly, 76% of the annual rainfall is received during June - September. The rainfall is monsoonal and unimodal. The south-west monsoon usually sets in around mid-June and recedes by mid-October.

Experimental design and treatments

The experiment was conducted in a randomized block design with 8 treatments and 3 replications. Treatments were : T₁-Control P; T₂-100%P (URP); T₃-100% P(SSP); T₄- 75% P (URP) + 25% P (SSP); T₅-50% P (URP) + 50% P (SSP); T₆-25% P (URP) + 75% P (SSP); T₇-200% P (URP) only on 1st crop; T₈- 100% P (SSP) + LIME@0.2 LR. EACH PLOT WAS 10 m x 10 m. The groundnut crop cv. TAG 24 of 115 days duration was sown during rabi 2013-14 and rabi 2014-15 at a spacing of 30x10 cm. Except the control treatment (T₁), the crop received recommended doses of N, P₂O₅, K₂O @ 20:40:40 kg ha⁻¹.

Control treatment (T_1) received only N and K_2O at 20 and 40 kg ha⁻¹ respectively. All N, P, K were applied as basal dose. Phosphorus was applied in all the treatments from T_2 to T_8 with the sources as per treatments. The hybrid maize crop cv. P-3441 of 90 days duration was sown during kharif 2014 and kharif 2015 at a spacing of 60 x 30 cm. Except the control treatment (T_1), the crop received recommended doses of N, P_2O_5 , K_2O @ 100:50:50 kg ha⁻¹. Control treatment (T_1) received only N and K_2O 100 and 50 kg ha⁻¹. The crop received one third dose of nitrogen, full dose of P and half dose of K as basal at the time of sowing. Rest one third dose of nitrogen and half dose of potash were applied at 25 DAS. Remaining one third dose of nitrogen was applied at 50 DAS. Phosphorus was applied in all the treatments from T_2 to T_8 as per treatments at sowing. A composite soil sample (0 -15 cm depth) was collected from the experimental site before sowing of seeds and fertilizers application.

Crop management

All the recommended agronomic practices i.e., irrigation, intercultural operations, pest control were uniformly kept in all the treatments as and when needed. The mean temperatures during groundnut crop growing seasons were 26.5°C and 28.0°C respectively while the relative humidity 67.6% and 67.0% respectively. The mean temperatures during hybrid maize crop growing seasons were 27.9°C and 28.8°C respectively while the relative humidity 83.7% and 82.3% respectively.

Soil sampling, processing and analysis

Soil samples (0-15 cm) were collected from each treatment replication wise at flowering (30 DAS), pod formation (60 DAS) and harvesting (115 DAS) stage of groundnut crop and knee-high (30 DAS), tasseling (60 DAS) and harvesting stage (90 DAS) stage of maize crop. The samples were air dried under shade, crushed with wooden hammer and passed through 2 mm sieve and preserved in polythene bags for analysis. Analyses were for: soil texture, bulk density, water holding capacity, pH, electrical conductivity, lime requirement value, organic carbon, exchange acidity, exchangeable acidity, exchangeable calcium, effective cation exchange capacity, available nitrogen, available phosphorus, available potassium, available sulfur. The texture of soil samples were determined with the help of Bouyoucous Hydrometer as given by Piper (1950) [13]. The bulk density of soil (undisturbed) was determined by Core method (Black, 1965) [1]. The water holding capacity of soil samples were determined by Keen Raczkowski Box method (Piper, 1950) [13]. The pH was determined in 1:2.5 soil-water ratio by pH meter (ELICO LI 613 pH meter) as described by Jackson (1973) [8]. As suggested by Jackson (1973) [8], the electrical conductivity of soil samples was determined in 1:2.5 soil-water suspension by conductivity meter (ELICO CM 180 Conductivity meter). Lime requirement value of soil was determined by Woodruff Buffer method (Woodruff, 1948). The organic carbon content of soil was determined by Wet digestion procedure of Walkley and Black (1934) [16] as outlined in soil chemical analysis (Page *et al.*, 1982) [12]. Exchange acidity, exchangeable acidity: Exchange acidity, exchangeable acidity were estimated by using the methods of Lin and Coleman (1960) [10] as described by Page *et al.*, (1982) [12]. Exchangeable Calcium was determined using EDTA (Versenate) complexometric titration by using Calcon indicator as outline by Hesse (1971) [7]. Effective Cation Exchange Capacity refers to the sum of the milli equivalents

of Ca, Mg, K, Na plus H and Al. Exchangeable Ca, Mg, K and Na were extracted using neutral normal ammonium acetate and determined separately. Available nitrogen in soil was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [15] using Kelplus nitrogen auto analyzer (Kelplus: Model classic DX). Available phosphorus in the soil was determined by Bray's 1 method (Bray and Kurtz, 1945) [2] as outlined by Page *et al.*, (1982) [12]. Available potassium was determined by extracting the soil with neutral normal ammonium acetate solution and estimated by flame photometer as described by Hanway and Heidal (1952) [6]. The available S content was determined turbidimetrically following the procedure of Chesnin and Yien (1952) [3] as described by Page *et al.*, (1982) [12].

Statistical analysis of data

The data from the experiment were analysed statistically following the procedure given by Gomez and Gomez (1984) [4]. Whenever the treatment differences were significant, critical difference were calculated at five per cent probability level and used for interpretations.

Results and Discussion

The soil of the experimental site is loam in texture with 64.6% sand, 14.8% silt and 20.6% of clay. The maximum water holding capacity is 31% with bulk density (BD) 1.59 Mg m⁻³. The soil is acidic in reaction (pH-5.18), non saline (EC- 0.09 dS m⁻¹) with exchangeable Al^{3+} and exchangeable H^+ of 0.05 and 0.06 c mol (p+) kg⁻¹ respectively. The soil is low in available N (239.0 kg ha⁻¹), medium in P (14.64 kg ha⁻¹) and K (150.0 kg ha⁻¹) and S (27.4 kg ha⁻¹) indicating low soil fertility. The CEC is 4.2 c mol (p+) kg⁻¹ soil and base saturation of 43%. The samples of URP used had 7.8% total P, 25.6% Ca, 0.26% Mg, 0.24% K and 1.2% S indicating a moderate reactivity of the material.

Exchangeable calcium in soil

The figures presented in 1 and 2 described the extent of exchangeable calcium at different growth stages of groundnut-maize cropping system. In control, exchangeable calcium decreased gradually from the initial value of 1.31 c mol (p+) kg⁻¹ to 1.24, 1.18 and 1.11 c mol (p+) kg⁻¹ at flowering, pod formation and harvest of first groundnut crop (rabi 2013-14). Similar trend was observed in sole URP treatment applied either to first crop (T_7) or to all crops (T_2). At harvest, the exchangeable calcium in T_2 and T_7 was 1.12 and 1.14 c mol (p+) kg⁻¹ respectively, lower than the initial value (1.31 c mol (p+) kg⁻¹).

In other treatments, the value of exchangeable calcium increased from initial value of 1.31 c mol (p+) kg⁻¹, attained the peak at flowering stage and there after gradually declined at pod formation and harvest stage. At flowering stage, maximum exchangeable calcium of 1.45 c mol (p+) kg⁻¹ was recorded in SSP + lime treatment (T_8) treatment followed by SSP (1.40 c mol (p+) kg⁻¹). The values varied between 1.34-1.38 c mol (p+) kg⁻¹, when crop received URP +SSP mixture in different ratio. The magnitude of exchangeable calcium in URP+SSP mixture was in the order of 1:3 >1:1 > 3:1. At harvest the exchangeable calcium content in P treatments varied between 1.12 to 1.23 c mol (p+) kg⁻¹ which was lower than initial value, indicating that higher amount of calcium was removed from the soil by groundnut. A Part of calcium might also be leached down ward through percolation with irrigation water.

Similar trend of exchangeable calcium was recorded during rest three cropping seasons. In control treatment, the exchangeable calcium content decreased from 1.11 to 0.96, 0.96 to 0.85 and 0.85 to 0.74 c mol (p⁺) kg⁻¹ during second, third and fourth season respectively. On the other hand, in other treatments, it increased from initial value and attained the peak at knee high stage of maize crop or flowering of groundnut crop, thereafter decreased gradually up to harvest. At harvest the values were lower than the initial value (Fig. 2) over three seasons. Further the data showed that, there was declined in exchangeable calcium content in soil even if the crop received full dose of P either through SSP or URP+SSP mixture. Application of lime with SSP also could not maintain the status of calcium in soil might be due to higher removal by groundnut and maize crop. Further a part of exchangeable calcium get leached down ward either through rain water during kharif season or irrigation water during rabi season might be due to coarse soil texture with high percolation rate. Leaching of calcium from maize root zone in acidic sandy loam soil was reported by Pradhan *et al.* (1982) [14].

The rate of dissolution of URP was also studied by Δ Ca method (Fig. 3). The change in Δ Ca due to dissolution of PR in sole URP treatment (T₂ and T₇) was marginally increased up to 30 DAS (flowering/knee high stage of crop), attained its peak at 60 DAS (pod formation/tasseling stage) and there after declined up to harvest indicating maximum dissolution occurs between 30-60 DAS. On the other hand, when crop received URP +SSP mixtures in different ratio, peak Δ Ca value was obtained at 30 DAS and there after declined at 60 DAS and harvest. This observation showed that addition of SSP as a starter dose enhanced the rate of dissolution of PR within 30DAS. Similar trend of URP dissolution was observed in subsequent seasons.

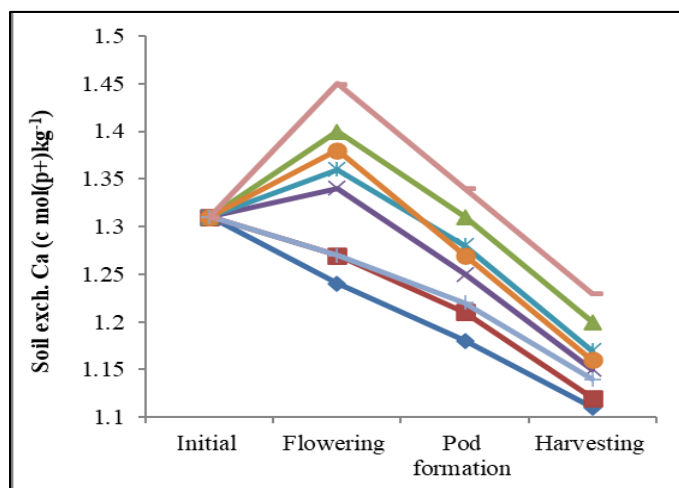
According to mass action law, PR dissolution releases Ca ion and soil with high Ca content would slow down PR

dissolution (Hammand *et al.*, 1986b) [5]. On the other hand, many tropical soils with low exchangeable Ca favour dissolution of PR. Soil having sandy texture with low CEC do not provide a sink for Ca ions released from PR, hence the PR dissolution is slowed resulting in reduction in PR efficiency (Kanabo and Gilkes, 1988a) [9].

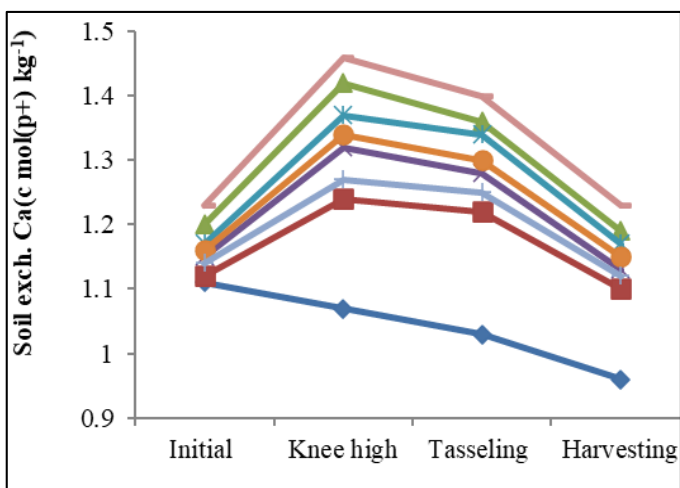
In a laboratory incubation study, Misra and Pattanaik (1997) [11] studied the effect of lime on dissolution characteristics of six Indian PRs and two imported PR (NCPR and Jordan) in a sandy loam soil with pH - 5.6, CEC - 3.1 c mol (p⁺)kg⁻¹, low in Bray's -P (3.4ppm) and Olsen's P (2.3ppm). The dissolution of PR consumed protons and release P and Ca. The release was highest during 30 to 45 days of incubation. More P and Ca was released from PR in unlimed soil as against limed one. The dissolution of different PRs in soil as indicated by change in soil pH, Δ P (0.5M NaOH extractable P in PR- control) and Δ Ca (exch. Ca in PR-control) reached equilibrium at 45 days of incubation due to build up of Ca and phosphate ions released from PR in soil solution due to inadequate size of sinks for these two ions in soil. Maximum percent of P dissolved was from Jordan PR (63.6%) followed by NCPR (61.4%) in limed soil. But these values were lower in unlimed soil.

Conclusion

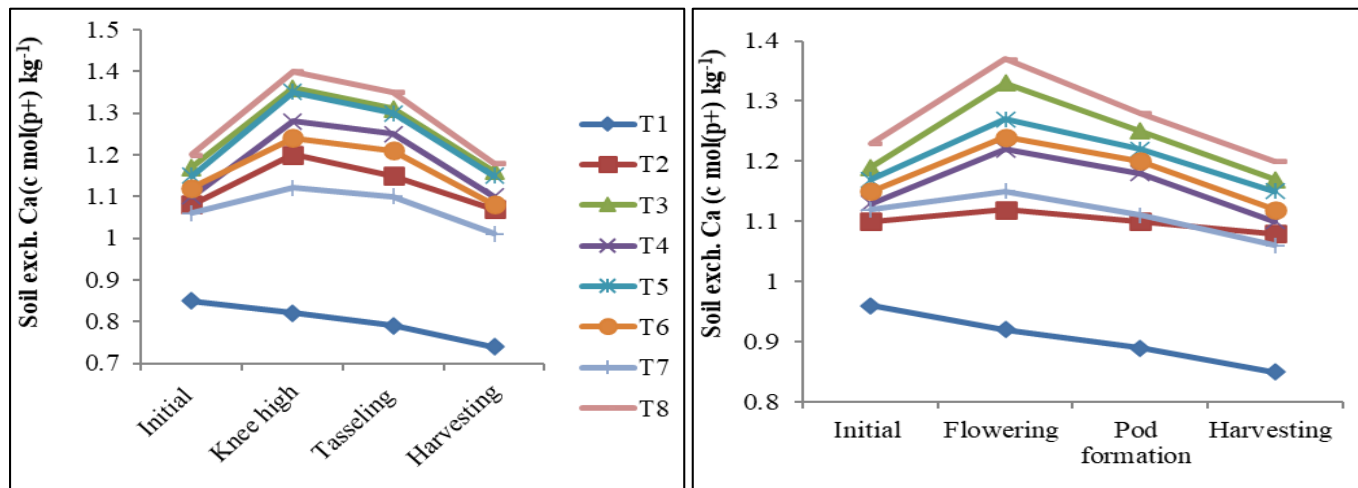
Based on Δ Ca method, the maximum dissolution of URP in the root zone of maize-groundnut cropping system occurred during 30-60 DAS after sowing. But when the crop received URP+SSP in 1:1 ratio, higher dissolution of URP occurred within 30 DAS. The rate of dissolution of URP in URP+SSP treatment is higher than the sole URP treatment. Also combined application of URP +SSP mixture in 1:1 ratio recorded higher soil exchangeable calcium as compared to standard SSP treatment.



a. Groundnut (Rabi 2013-14)



b. Maize (Kharif 2014)



c. Groundnut (Rabi 2014-15)

d. Maize (Kharif 2015)

Fig 1(a, b, c, d): Effects of treatments on soil exchangeable calcium content (c mol (p⁺) kg⁻¹) at different growth stages of groundnut and maize

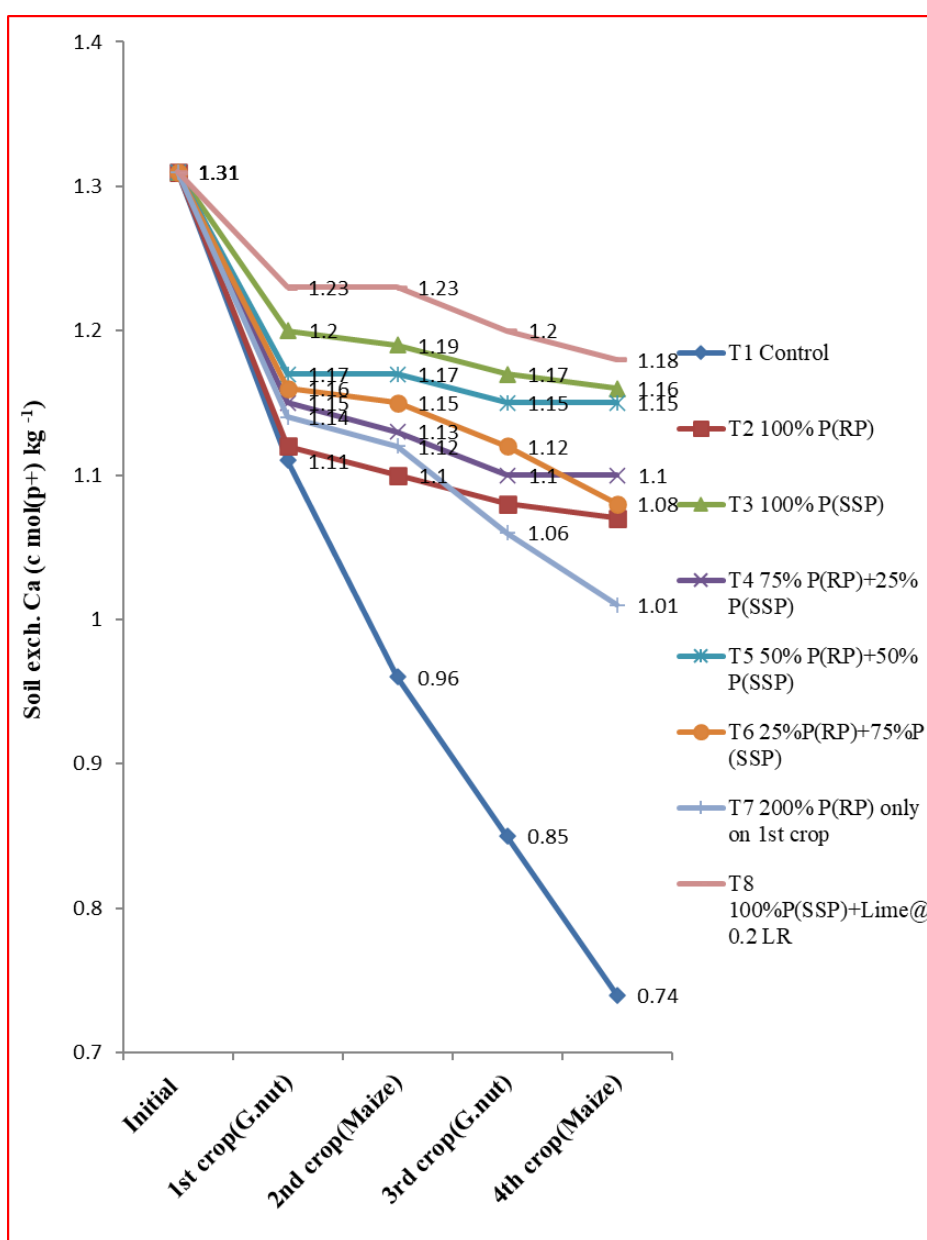


Fig 2: Effects of treatments on soil exchangeable calcium (c mol(p⁺) kg⁻¹) at harvest of crops over four seasons

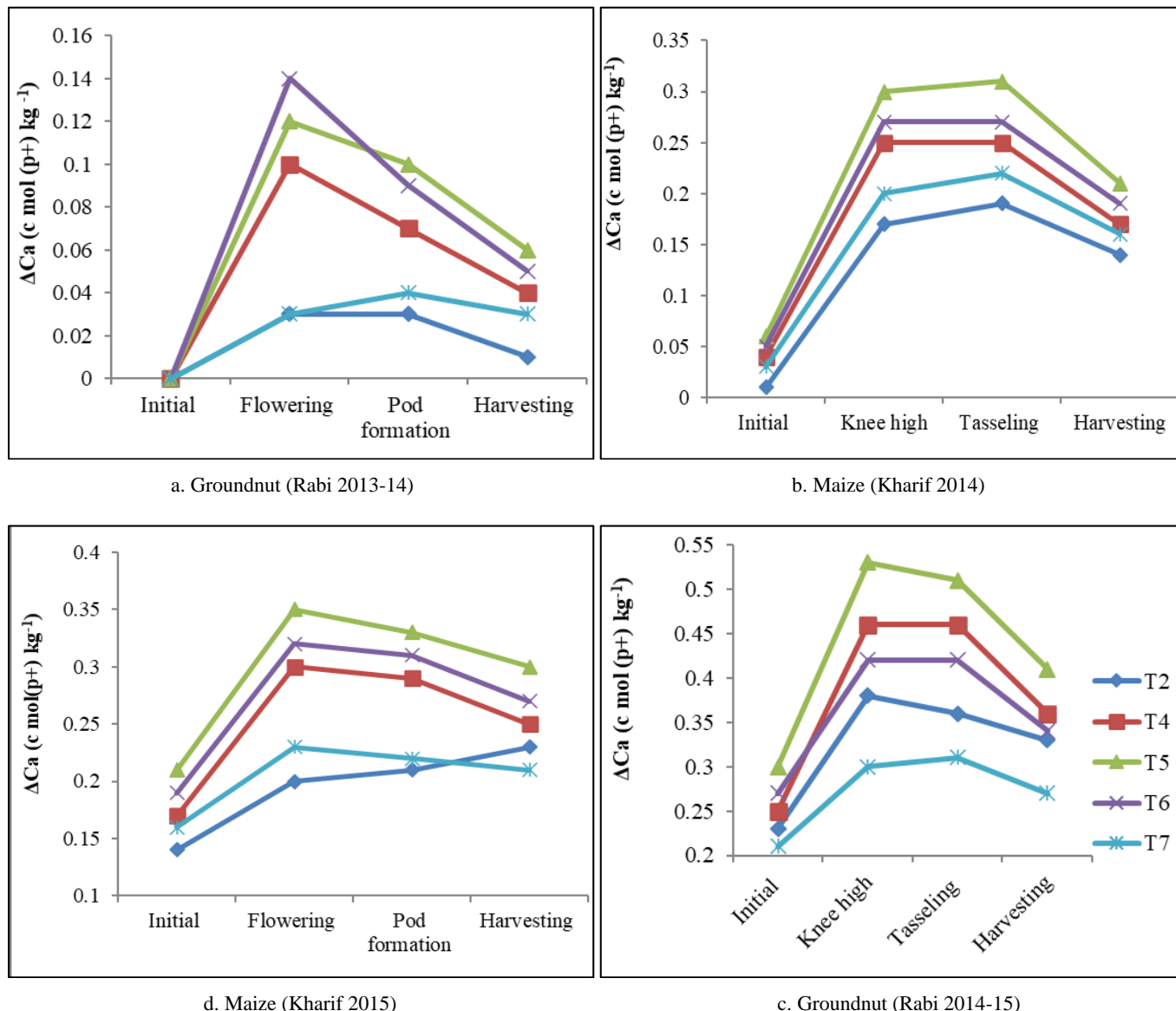


Fig 3(a, b, c, d): Effect of treatments on ΔCa at different growth stages of groundnut-maize cropping system

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