Global Research journal of Natural Science and Technology (Grjnst)
Volume: 04 - Issue 1 (2026)
p.ISSN: 2790-7643e.ISSN: 2790-7651

Calcium Dynamics in Pakistani Agroecosystems: A review

Hafiz Tanvir Ahmad
Lecturer, Department of Soil Science ISWR Islamia University of Bahawalpur
hafiz.tanvir@yahoo.com
Muhammad Hanzala Mansha
Student, Department of Soil Science ISWR, The Islamia university of Bahawalpur
manshahanzala@gmail.com
Tanzila Aslam
Senior Scientific Assistant (Pakistan Navy) and Government College Women University, Faisalabad
tanzilaaslam@gcwuf.edu.pk

Tahir Islam
Assistant Professor, Department of Entomology, Faculty of Agriculture, Gomal University, D. I. Khan.
drtahirislam@gu.edu.pk

Ayatullah
Assistant Professor, Department of Entomology, Faculty of Agriculture, Gomaluniversity, D. I. Khan.
ayatullah@gu.edu.pk

Muhammad Tahir Akbar
Senior Scientist (Agricultural Chemistry), Soil and Water Testing Laboratory Muzaffargarh
tahirakbar.ao@gmail.com

Muhammad Ibrar Ahmad
Scientific officer, Fodder research institute Sargodha
Muhammad.ibrar@aari.punjab.gov.pk

Rizwana Kausar
Senior Scientist, Soil and Water Testing Laboratory for Research, Sargodha
rizwana.kausar@aari.punjab.gov.pk

Corresponding Author Email; Muhammad.ibrar@aari.punjab.gov.pk

DOI:https://doi.org/10.53762/grjnst.04.01.08

Abstract:

Calcium (Ca) is important for maintaining soil structure, supporting plant growth, and human nutrition, yet its distribution and use in Pakistan are not fully understood. In this review we will discuss about current data available on exchangeable calcium in Pakistani soil and elaborate notable differences across different regions and soil conditions. Ca play important roles in plants including strengthening cell wall, supporting membrane functions, shaping root system and helping plants withstand environmental stress. In this review we will also discuss how calcium can improve soil health mainly in the acidic and sodic soils. Also discuss about some common Ca containing fertilizers available in Pakistan and their role and working in different soil condition and gain understanding about why Pakistani people especially women suffer from Ca deficiency even it is abundant in most Pakistani soils. In this article we combine different aspects from agriculture to human health and highlighting key gape in knowledge and different strategies to improve Ca management for soil and plants growths.

Keywords: Calcium (Ca); Exchangeable calcium; Pakistani soils; Soil fertility; Plant nutrition; Calcium fertilizers; Soil health; Human calcium deficiency

Introduction:

Calcium (Ca) plays an important role in agriculture worldwide, but its behavior in Pakistani soils is complex and sometimes contradictory. Most of Pakistan's agro-ecological zones consist of calcareous soils having high pH (above 7.5-8.0) because of large amount of calcium carbonate in the parent material which strongly effect how Ca is available and cycle through the soils (Arain et al., 2017). Even these soils are rich in Ca but in many areas crops are facing Ca deficiencies which effect plants health and eventually the yield. This happen because calcium solubility and adsorption by plants depends on different factors like soil alkalinity, low organic matter and soil texture (Rahim et al., 2006). More over calcium interaction with other elements like magnesium and sodium effect nutrient balance and how crop react to it (Rahim et al., 2006).

Calcium is essential for plants in many ways. It provides structural support in cell walls and membranes, and serves as a universal secondary messenger inside cells, controlling growth, development, and how plants react to environmental stresses (Hepler, 2005). It also helps regulate stomata, supports nutrient uptake, and strengthens the plant's ability to tolerate stress, which is especially important for sustainable agriculture in Pakistan's tough climate (Khan et al., 2023; Weng et al., 2022). Beyond its role in plants, calcium is crucial in reclaiming problematic soils, such as saline and sodic soils widespread across irrigated regions in Pakistan. Here, calcium amendments like gypsum and calcium chloride improve soil structure and fertility by reducing sodium toxicity and enhancing nutrient absorption (Niamat et al., 2019). These improvements not only boost calcium availability but also restore soil health, helping maintain resilient and productive farming systems.

…

Although calcium is present in abundance in Pakistan's soils, yet Pakistan face Ca deficiency among the population due to limited bioavailability of Ca in the staple food and dietary sources (Niaz, 2007). This state indicates close link between soil calcium level, calcium absorption efficiency of plants, crop's nutrient quality and human health.To overcome these problems, it is essential to focus on the integrated approaches which help maintain soil health, improve calcium uptake efficiency, improve Ca level in food and better Ca availability for population.

Role of Ca in Plants:

Calcium plays a crucial role in maintaining plant health. It plays crucial role in maintaining cell wall structure, communication signaling, activate enzymes and help plants to tolerate stress. In cell wall structure Ca forms calcium pectate that helps stabilize and strengthen middle lamella, which stick cells together thus maintain cell wall and plants tissue stability (White, 2003). Ca maintain the permeability of cell wall thus regulate the movement and transportation throughout plants. It act as a secondary messenger inside plants cells. Ca plays crucial role in the hormones response, plants defence mechanism against environmental stress such as salinity, drought, flooding and attack of pathogen by transmitting signals (Feng et al., 2023; Bhar et al., 2023). Calcium triggers sensors and enzymes such as protein kinases, which then effect gene expression and protein functions, helping the plant grow well and withstand stress(Khan et al., 2023). For example Ca induce defense mechanism in the plants against microbial pathogen through production of reactive oxygen species and activate defense genes through PAMP triggered immunity and effector triggered immunity (Bhar et al., 2023; Wang, 2024). Calcium work in connection with plant hormones such auxin, cytokinins and gibberellins to help coordinate with different stages of plant growth. Researcher have found a particular Ca binding proteins that not only help plants response to auxin but also maintain Ca level inside the cell. These connections link hormones signals with how plants adjust their growth and adapt themselves with environmental conditions (Yalovsky et al., 2019). In addition Ca maintain photosynthesis under stressful conditions like salt exposure. It enhances the activity of antioxidant enzymes and helps keep chloroplasts stable, which is important for maintaining photosynthesis when plants face tough environmental conditions (Xu et al., 2017; Weng et al., 2022). Having adequate Ca benefits overall plant health by improving root and shoot growth, encourage flower and fruit development and improve nutrient uptake of key nutrients including nitrogen, phosphorus and potassium. It also prevents physiological disorder like blossom end rot by strengthening cell membranes and walls (Hepler, 2005; Demarty, 1984). However, both excess and deficiency of Ca can interfere with nutrient metabolism and cause abnormalities, emphasizing the need of balance Ca nutrition (Weng et al., 2022).

Calcium Availability Issues in Pakistan:

In Pakistan Ca availability and uptake is continue to be a significant challenge due to soil's characters and farming techniques. Most agricultural lands in the country are calcareous having high pH ranging above 7.5 to over 8.5 in some areas and are rich in calcium carbonate, which strongly effect Ca solubility and bioavailability (Bolan et al., 2023). Although, these soils are rich in Ca content, alkaline conditions create a chemical environment that bind Ca tightly to soil particles this make it harder for Ca diffusion and plant uptake. This situation further got worse by low organic matter level in the soil which further limit the nutrient mobilization (Memon et al., 2023).

Recent studies of Sindh and Punjab soils highlights that the Ca availability is limited by soil salinity and sodicity issues, where sodium ion compete Ca on the root exchange site, reducing Ca uptake and causing damage to soil structure (Memon et al., 2023). This excess sodium not only elevate ionic imbalance but also leads to poor soil aggregation and water permeability by displacing Ca from exchange sites. This also slow down the root growth and nutrient uptake. Moreover, improper use of fertilizers and lack of site specific nutrient management have made Ca deficiency more common in the crops, despite high Ca reserves in the soils (Memon et al., 2023; Ali et al., 2014). Soil texture and depth variations effects Ca uptake kinetics to large extent. Bioavailability of Ca in the deeper layer is low and root system may be insufficiently developed by adverse soil condition, this reduce the Ca uptake efficiency of roots (Ali et al., 2014). Research also shows that the Ca availability is closely linked with uptake of other essential nutrients like potassium and magnesium. With high level of Ca some time limit the uptake of other cations due to competition between cations, highlighting the importance of maintaining the nutrient balance (Wakeel et al., 2017).

To tackle these challenges, recent studies suggest integrated soil fertility programs that incl7de Ca based amendment like gypsum. These amendments help replacing sodium ion thus improving soil structure and improve bioavailability of Ca (Bolan et al., 2023). In addition to these amendments, site specific fertilization and organic matter applications are critical in sustainable agriculture and boosting crop yield in Pakistani agroecosystems.

Role of Ca in Reclaiming Soil:

Ca plays essential role in reclamation of degraded soil by improving soil physical, chemical and biological properties. One of the key role that Ca perform in soil reclamation, mainly the saline and sodic soils is through replacing toxic sodium ions from the exchange sites. This exchange helps improve soil structure by promoting soil particles aggregation and reducing soil dispersion. As a results water infiltration and root penetration become easy (Kinraide, 1998). Some commonly used Ca amendments include gypsum and calcium chloride which supply soluble calcium that replace sodium on exchange sites, thereby restoring soil permeability and fertility (Singare, 2022).

Calcium plays an important role in how organic compounds and minerals interact, which helps maintain the level of soil organic carbon (SOC). It supports the formation of mineral-associated organic matter (MAOM), stabilizing organic carbon in the soil by encouraging microbial residues and decomposed plant materials to attach and bind to mineral surfaces

…

(Shabtai et al., 2023).This process not only helps build up carbon storage in the soil but also provides nourishment that supports the microbial communities vital for maintaining soil health and nutrient cycling.Calcium creates a better environment for plant growth by improving soil pH, especially in alkaline and calcareous soils, and by lowering soil salinity and alkalinity. Calcium-containing amendments, such as calcium lactate, have been shown to lower soil salinity and improve soil structure by encouraging bonds like bridging and hydrogen bonding between soil particles (Fan et al., 2025). Additionally, applying amendments like calcium carbonate helps form larger soil aggregates and strengthens soil structure, which in turn improves soil aeration and helps retain moisture (Xie et al., 2024).New calcium-based reclamation methods, such as calcium-iron modified biochar, have recently proven to be a sustainable and environmentally friendly way to reclaim saline-alkali soils by improving nutrient availability and creating conditions that support beneficial microbes (Zhang et al., 2024). Through these various mechanisms, calcium plays a vital role in maintaining soil health, boosting soil fertility, and supporting a healthy agricultural ecosystem.

Table:1.Role of calcium in Soil Reclamation.

Role of Calcium in Soil Reclamation	**Mechanism**	**Agricultural Benefits**	**References**
Sodium displacement in sodic soils	Calcium reduce ESP and SAR by replacing sodium on soil exchange sites.	This improves soil structure, water infiltration, and permeability	Kinraide, 1998; Singare& Singh, 2022
Calcium promote soil aggregates formation	Calcium promote flocculation of clay particles and stabilizes aggregates	This improve aeration, water retention, root penetration	Bolan et al., 2023; Pure Milieu, 2023
Calcium promotes stabilization of soil organic matter	Calcium promote binding of organic compounds to mineral surfaces	Increases soil carbon sequestration and microbial activity	Shabtai et al., 2023
Buffering soil pH and reduce soil salinity reduction	Calcium-containing amendments neutralize alkalinity and reduce salinity	Creates favorable conditions for crop growth	Fan et al., 2025; Xie et al., 2024
Ca improve soil porosity and aeration	Improves pore size distribution facilitating gas exchange and water movement	Supports healthy root development and drought resilience	Pure Milieu, 2023; Kynoch, 2024
Enhancement of soil microbial activity	Calcium promotes growth of beneficial soil microbes	Boosts nutrient cycling and organic matter decomposition	Pure Milieu, 2023

Use of calcium-iron amendments	Calcium-iron biochar improves nutrient availability and soil structure	Sustainable reclamation of saline-alkali soils	Zhang et al., 2024
Remediation of soil compaction	Soluble calcium loosens compacted soils	Facilitates root growth and ease of soil management	Kynoch, 2024; OneTetra, 2024

List of Ca containing fertilizers in Pakistan:

Table:2. List of Ca containing Fertilizers in Pakistan, benefits and Harms

Ca Fertilizer Form in Pakistan	Uses in Different Soil Types	Benefits	Harms of Using Them	References
Calcium Ammonium Nitrate (CAN)	This is suitable for neutral to slightly alkaline soils	Supplies nitrogen and calcium; improves crop yield	Potential misuse and regulation may cause few environmental issues	Sarsabz, 2024; Dawn News, 2023
Calcium Nitrate	Give better results in sandy, calcareous, and saline soils	Contain readily available Ca and N; supports fruit quality	Excess application can cause nitrate leaching	IR Farm, 2025
Calci Plus (Ca + Micronutrients)	Effective in nutrient-deficient and calcareous soils	Supplies calcium and essential micronutrients	If not properly used induce the risk of nutrient imbalance	Ali Agro, 2024
Calcium Boron Liquid Fertilizer	Effective in micronutrient-sensitive crops and calcareous soils	Improve fruit set, disease resistance, and quality	Excess boron toxicity possible if overdosed	Shah Chemical, 2024
Gypsum (Calcium Sulfate)	Used in sodic and saline soils	Displaces sodium, improves soil structure	Can acidify soil over time if applied excessively	Singh & Singh, 2022; Bolan et al., 2023

Calcium deficiency Issues in People of Pakistan:

Despite calcium being an abundant element in Pakistani soil, its deficiency remains a widespread issue in Pakistani people. This is mainly due to several dietary, physiological and socioeconomic factors. Recent studies find that more than 90% children in the flood effected

areas of KPK are effected with calcium deficiency and many of them facing problems like weak bones and dental issues (UlHaq et al., 2021). Dietary intake of Ca is very low as staple diet lack sufficient calcium rich foods, like dairy products, green leafy vegetables and fortified sources (Afeiche et al., 2024). Limited exposure to sunlight due to life style factors mainly in the women and children cause problem like deficiency of vitamin D, whose deficiency reduce calcium absorption efficiency (Abbas et al., 2025; Thejas, 2025). Women are particularly at risk due to pregnancies and lactation, which enhance calcium demand, and if unmet it leads to osteoporosis and fractures later in the life (Brecorder, 2025). Lack of public awareness and limited availability of calcium supplement mainly in the rural and poorer communities make matter worse (Haleon Health Partner, 2008; Women of Strength, 2024). This creates public health paradox where Ca is abundant in the soil but unable to translate to human nutrition, because of micro nutrient deficiencies, diet habits and social factors. Addressing these problems in Pakistan require integrated approaches like educating peoples on nutrition, fortifying food with calcium and vitamin D, running supplementation programs and promoting more diverse food to enhance Ca intake and absorption (Khan et al., 2013; UlHaq et al., 2021).

Conclusion:

Calcium is an important element in Pakistani agriculture system, from playing key role in soil health, supporting plant growth and human nutrition. In calcareous and alkaline soils calcium is present in abundance but its availability to plants is limited due to high pH, excess of sodium and soil texture which make it harder for plants to uptake Ca and reduce plants yield. Alongside with structural component of cell wall, Ca regulate growth, stress tolerance and nutrient uptake by inducing signaling pathways. Ca amendments like gypsum and calcium nitrate are important in reclaiming sodic and saline soils by displacing sodium and promoting aggregates formation. Pakistani people are facing clear paradox in human nutrition even of Ca abundance in soils due to poor dietary intake, vitamin D deficiency and sociocultural practices mainly in the women and children. To address these challenges require integrated approaches like educating people, food fortification and public health intervention addressing vitamin d and Ca intake. Improving bioavailabilty of Ca in soil by developing nutrient efficient crops and ensuring fair access to nutrient rich diet thus will together promote healthy agro ecosystems and populations.

References:

1. Arain, M.Y., Memon, K.S., Akhtar, M.S. and Memon, M., 2017. Soil and plant nutrient status and spatial variability for sugarcane in lower Sindh (Pakistan). Pak. J. Bot, 49(2), pp.531-540.

2. Rahim, S.M.A., Hasnain, S. and Farkhanda, J., 2011. Effect of calcium, magnesium, sodium and potassium on farm plantations of various agroecological zones of Punjab, Pakistan. Afr. J. Plant Sci, 5(5), pp.450-459.
3. Hepler, P.K., 2005. Calcium: a central regulator of plant growth and development. The Plant Cell, 17(8), pp.2142-2155.
4. Khan, F.S., Goher, F., Paulsmeyer, M.N., Hu, C.G. and Zhang, J.Z., 2023. Calcium (Ca2+) sensors and MYC2 are crucial players during jasmonates-mediated abiotic stress tolerance in plants. Plant Biology, 25(7), pp.1025-1034.
5. Niamat, B., Naveed, M., Ahmad, Z., Yaseen, M., Ditta, A., Mustafa, A., Rafique, M., Bibi, R., Sun, N. and Xu, M., 2019. Calcium-enriched animal manure alleviates the adverse effects of salt stress on growth, physiology and nutrients homeostasis of Zea mays L. Plants, 8(11), p.480.
6. Weng, X., Li, H., Ren, C., Zhou, Y., Zhu, W., Zhang, S. and Liu, L., 2022. Calcium regulates growth and nutrient absorption in poplar seedlings. Frontiers in plant science, 13, p.887098.
7. Niaz, A., 2007. Boron deficiency in high pH and calcareous soils of Pakistan: implications for human nutrition. Pakistan Journal of Agriculture, 44(2), 225-234.
8. Demarty, M., Morvan, C. and Thellier, M., 1984. Calcium and the cell wall. Plant, Cell & Environment, 7(6), pp.441-448.
9. Feng, D., Wang, X., Gao, J., Zhang, C., Liu, H., Liu, P. and Sun, X., 2023. Exogenous calcium: Its mechanisms and research advances involved in plant stress tolerance. Frontiers in Plant Science, 14, p.1143963.
10. Xu, D., Wang, W., Gao, T., Fang, X., Gao, X., Li, J., Bu, H. and Mu, J., 2017. Calcium alleviates decreases in photosynthesis under salt stress by enhancing antioxidant metabolism and adjusting solute accumulation in Calligonummongolicum. Conservation Physiology, 5(1), p.cox060.
11. Yalovsky, S., et al.,2019. How a protein connecting calcium and plant hormone regulates plant growth. PLOS Biology, 17(7), e3000409.
12. Wang, Q., Cang, X., Yan, H., Zhang, Z., Li, W., He, J., Zhang, M., Lou, L., Wang, R. and Chang, M., 2024. Activating plant immunity: the hidden dance of intracellular Ca2+ stores. New Phytologist, 242(6), pp.2430-2439.
13. Ali, S., Niazi, N. K., & Khan, M. A., 2014. Imbalanced use of fertilizers and its effect on crop productivity in Sindh soils. Journal of Soil Science and Plant Nutrition, 14(4), 987-995.
14. Bolan, N., Srivastava, P., Rao, C.S., Satyanaraya, P.V., Anderson, G.C., Bolan, S., Nortjé, G.P., Kronenberg, R., Bardhan, S., Abbott, L.K. and Zhao, H., 2023. Distribution, characteristics and management of calcareous soils. Advances in agronomy, 182, pp.81-130.
15. White, P. J., 2003. Calcium in plants. Plant, Cell & Environment, 26(9), 1499-1509.
16. Bhar, A., Chakraborty, A. and Roy, A., 2023. The captivating role of calcium in plant-

microbe interaction. Frontiers in plant science, 14, p.1138252.

17. Memon, A.A., Rajpar, I., Jamro, G.M. and Shah, J.A., 2023. Soil and associated plant potassium status of sunflower in lower Sindh (Pakistan). Pak. J. Bot, 55(5), pp.1879-1885.

18. Wakeel, A., Farooq, M., & Wang, D., 2017. Cation interactions and nutrient management in calcareous sodic soils. Soil Science & Plant Nutrition, 63(5), 527-535.

19. Talpur, M. A., et al., 2016. Potassium availability and its impact on crop yield in calcareous soils of lower Sindh. Soil & Environment, 35(1), 12-19.

20. Fan, J., Lv, Q., Zhou, T., Wang, T., Gao, H., Zhou, W., Ren, X. and Hu, S., 2025. Calcium lactate as a soil amendment: Mechanistic insights into its effect on salinity, alkalinity, and aggregation in saline-alkaline soils. Soil and Tillage Research, 248, p.106459.

21. Kinraide, T.B., 1998. Three mechanisms for the calcium alleviation of mineral toxicities. Plant Physiology, 118(2), pp.513-520.

22. Shabtai, I. A., et al., 2023. Calcium drives soil organic carbon persistence through associations between organic compounds and minerals. Nature Communications, 14, Article 6599.

23. Singare, P., Meshram, N. and Kausadikar, H., 2022. Calcareus soil and their management: A review. Just Agric, 3(4), pp.2582-8223.

24. Xie, J., Gao, J., Cao, H., Li, J., Wang, X., Zhang, J., Meng, H., Hong, J., Li, T. and Xu, M., 2024. Calcium carbonate promotes the formation and stability of soil macroaggregates in mining areas of China. Journal of Integrative Agriculture, 23(3), pp.1034-1047.

25. Li, X., Sun, K., Cao, J., Wu, L., Zheng, A., Jiang, S. and Zhao, W., 2024. The Amelioration Effect and Mechanism of Calcium-Iron Modified Biochar on Coastal Saline-Alkali Soil. Jingguo and Wu, Li and Zheng, Aijun and Jiang, Shengguo and Zhao, Wenjie, The Amelioration Effect and Mechanism of Calcium-Iron Modified Biochar on Coastal Saline-Alkali Soil.

26. Pure Milieu., 2023. The benefits of calcium sulphate use in soil & agriculture. Pure Milieu Technical Report

27. Kynoch. (2024). Making the most of Calcium (Ca) as a soil plant nutrient. Kynoch Fertilizer.

28. OneTetra. (2024). Repairing soil with liquid calcium chloride. OneTetra Agriculture Solutions.

29. Ali Agro. (2024, March 9). Calci Plus (Ca 20+TE) - Calcium and micronutrients fertilizer. Retrieved October 4, 2025, from https://aliagro.com.pk/product/calci-plus-calcium-micronutrient-fertilizer/

30. Dawn News. (2023, December 11). KP's agriculture dept directed to confiscate ammonium nitrate fertilizers. Dawn. Retrieved October 4, 2025, from https://www.dawn.com/news/1796864

31. IR Farm. (2025, May 6). Vita-Can Calcium Nitrate Fertilizer 25kg with Boron. Retrieved

October 4, 2025, from https://irfarm.com/products/vita-can-calcium-nitrate-fertilizer-25kg
32. Sarsabz. (2024, November 5). Calcium Ammonium Nitrate. Retrieved October 4, 2025, from https://growpak.store/product/calcium-ammonium-nitrate/
33. Shah Chemical. (2024, October 16). Calcium Boron (Liquid Fertilizer) Made in China. Retrieved October 4, 2025, from https://shahchemicalpk.com/products/calcium-boron-liquid-fertilizer-1-litre
34. Singh, J., & Singh, A., 2022. Calcareous soil and their management – A review. Soil Science Society of Nepal Journal, 5(1), 15-25.
35. Abbas, A., Abbas, T., Ahmad, I., Mubeen, A., Iqbal, S., Hameed, F. and Fatima, R., 2025. Association Between Vitamin D Deficiency and Calcium Status in School-Aged Children and Adolescents in Lahore. Journal of Health, Wellness, and Community Research, pp.e195-e195.
36. Afeiche, M.C., Zimmermann, D., Donato-Capel, L., Achakzai, B.K. and Mak, T.N., 2024. Consumption of Milk Beverages Reduces Iron, Vitamin A, Vitamin C, Calcium, and B Vitamins Inadequacies in Pakistani School-Aged Children from Sindh and Punjab: A Diet Modeling Study. Current Developments in Nutrition, 8(9), p.104435.
37. Brecorder. (2025, January 5). Over 75% of Pakistani women suffer from calcium deficiency. Business Recorder. Retrieved October 4, 2025, from https://www.brecorder.com/news/40341217

38. Haleon Health Partner., 2008. Nutritional deficiencies – causes and mechanisms. Retrieved October 4, 2025, from https://www.haleonhealthpartner.com/en-pk/wellness/conditions/nutritional-support/causes-and-mechanisms/
39. Khan, A. H., et al., 2013. Assessing the effect of dietary calcium intake and vitamin D on bone health in Pakistani females. PLoS One, 8(12), e81044.
40. UlHaq, I., et al., 2021. Prevalence of micronutrient deficiencies among preschool and school-age children in flood-affected areas of Khyber Pakhtunkhwa, Pakistan. Nutrients, 13(10), 3663.
41. Women of Strength. (2024). The growing issue of calcium deficiency among women in Pakistan. CCL Holding. Retrieved October 4, 2025, from https://cclholding.com/women-of-strength/
42. Thejas., 2025. Vitamin D levels and bone-related biochemical markers among Pakistani population. Pakistan Journal of Health Sciences, 15(1), 42-50.