**Effect of organic amendments and micronutrient foliar application on finger millet (*Eleusine coracana* L.) productivity under calcareous soil**

**Aims:** To study the effect of organic amendments and micronutrient foliar application on growth and yield of finger millet under calcareous soil conditions.

**Study design:** Factorial Randomised Block Design

**Place and Duration of Study:** The field experiment was carried out during the rabi season from

September 2024 – December 2024 at Instructional south farm in Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu.

**Methodology:** The field trial was laid out with three replications the treatments comprised of soil amendments in factor (S) *viz.,* S1- Pongamia seed cake @ 1.46 t ha-1 +100 %RDF, S2 - Neem seed cake @ 1.25 t ha-1 + 100 % RDF, S3- Castor seed cake @ t ha-1 + 100 % RDF, S4 - FYM @ 12.5 t ha-1 + 100 % RDF, S5- 100% RDF alone (Control), respectively in factor S and foliar application of micronutrients in factor F *viz.,* F1- Fe-EDTA 0.2% @ 30 and 45 DAS, F2- Zn-EDTA 0.2% @ 30 and 45 DAS, F3- Mn-EDTA 0.2% @ 30 and 45 DAS, F4- No spray (Control).

**Results:** The results showed that the application of Pongamia seed cake @ 1.46 t ha-1+100% RDF + Fe-EDTA 0.2% @ 30 and 45 DAS significantly improved the physiological parameters, such as RGR and NAR, and the growth characteristics, such as LAI, number of leaves per plant, and stem girth, with higher grain yield (2891 kg ha-1) and straw yield (5752 kg ha-1).

**Keywords:** Amendment, Calcareous Soils, Finger Millet, Micronutrients, Pongamia cake.

**1.Introduction**

Millet, a cereal grass cultivated for edible seeds, is a nutrient-rich grain with a high iron content. Originating in Asia and Africa over 4,000 years ago, it was a staple in Europe during the Middle Ages. Millet contains protein, fat, Vitamin E, B complex vitamins, and essential amino acids, making it a beneficial health food (Himanshu *et al.,* 2018). India is the world's largest millet producer, contributing 19% to global millet production in 2022. With 12.45 million hectares, Rajasthan dominates millet cultivation, followed by Maharashtra and Karnataka (Agriculture Statistics at a Glance 2022). Finger millet, a staple food crop in Asia and Africa, is a nutritious cereal with 8.1% protein, 1.5% fat, and 68.1% starch. It contains 22% total dietary fibre, 1.9% mineral content, and 65-75% carbohydrates (Shobana *et al.,* 2006). India is the world's largest finger millet producer, with 2 million tons produced in 2021, followed by Ethiopia. With 19.85 lakh metric tonnes and a productivity rate of 1724 kg ha⁻¹, Karnataka (64.8%) dominates production, followed by Tamil Nadu (7.1%) and Maharashtra (5.4%) (Milletstats, 2022). Calcareous soils, found in dry and semi-arid climates, cover 1.5 billion acres and account for 17% of global soils. In India, they cover 69.4% of the country's total area, with Tamil Nadu covering 6-8% of its 13 million hectares (Pal *et al.,* 2000). Soils with high carbonate levels can cause nutrient deficiencies, particularly limiting the availability of nitrogen, phosphorus, iron, and zinc. This leads to issues like lime-induced iron chlorosis, reduced seed germination, and poor water retention due to structural changes such as hardpan formation, which restrict root growth and water infiltration (Taalab *et al.,* 2019; Virto *et al.,* 2018). High sodium carbonate levels may raise soil pH above 9. Synthetic fertilizers are less effective in calcareous soils due to nitrogen loss through ammonia volatilization and phosphorus fixation into insoluble forms. Organic amendments help stabilize pH, improve soil structure, porosity, water-holding capacity, and overall soil health (Zaki *et al.,* 2011). EDTA formulations effectively manage micronutrients, alleviating plant stress in calcareous soils. They enhance chlorophyll content, promote photosynthesis, and reduce nutrient stress, enhancing plant resilience and boosting crop growth (Shalini *et al.,* 2023). Organic fertilizers enhance soil health and microbial activity, while chelated micronutrients address iron chlorosis in calcareous soils. Combining organic amendments with chelated micronutrients boosts crop growth and yields (Zaki *et al.,* 2011).

**2. MATERIALS AND METHODS**

**2.1 Location of the Experimental Site**

The field experiment was conducted at Instructional South farm, Karunya Institute of Technology and Sciences, Coimbatore. The experimental site is geographically located in the western zone of Tamil Nadu at 10º N latitude and 76º E longitude at an altitude of 474 m above mean sea level.

**2.2 Season and Crop Varieties**

The study was conducted during the season of *rabi* from September 2024 to December 2024. The variety selected as finger millet was ATL 1 with a duration of 95-110 days.

**2.3 Experimental Design**

The field trial was laid out in factorial randomised block design with three replications the treatments comprised of soil amendments in factor (S) *viz.,* S1 -Pongamia seed cake @ 1.46 t ha-1 +100 %RDF, S2 - Neem seed cake @ 1.25 t ha-1 + 100 % RDF, S3- Castor seed cake @ t ha-1 + 100 % RDF, S4 - FYM @ t ha-1 + 100 % RDF, S5- 100 % RDF alone (Control), respectively in factor S and foliar application of micronutrients in factor F *viz.,* F1- Fe-EDTA 0.2% @ 30 and 45 DAS, F2- Zn-EDTA 0.2% @ 30 and 45 DAS, F3- Mn-EDTA 0.2% @ 30 and 45 DAS, F4- No spray (Control).

**2.4 Soil Characteristics**

The experimental field soil is clay loam with an initial pH of 8.63 (1:2 soil-water suspension), EC of 0.23 dS m-1, and organic carbon of 0.24%. It contains available N 210.75 kg ha-1, P 12.24 kg ha-1, K 174.36 kg ha-1 and free CaCO3 12.5%.

**2.5 Application of soil organic amendments and micronutrients**

Organic amendments were applied one week before crop transplanting, based on nutrient equivalent rates. Pongamia cake, neem cake, and castor seed cakes were evenly distributed and irrigated to improve soil fertility. This approach promotes steady fertilizer release and sustainable nutrient management. A foliar spray of Fe-EDTA, Zn-EDTA, and Mn-EDTA was also given at the vegetative stage and flowering stage of crop.

**2.6 Experimental Observations**

**2.6.1 Leaf Area Index**

Leaf area was measured at 30, 60 DAS, and harvested using a leaf area meter. Leaf Area Index (LAI) was calculated using formula (Williams, 1946).

**2.6.2 Number of leaves**

The number of leaves of finger millet was recorded at 30, 60 DAS and at harvest stage.

**2.6.3 Stem girth**

The stem girth of finger millet was measured at 30, 60 DAS and at harvest stage.

**2.6.4 Relative growth rate**

RGR measures the increase in plant biomass per unit of existing biomass over a given time period, reflecting the plant's efficiency in accumulating dry matter relative to its size (Radford, 1967).

**2.6.5 Net Assimilation Rate**

Net Assimilation Rate (NAR) is the rate of biomass gain per unit of leaf area, representing the efficiency of leaves in producing dry matter through photosynthesis over a specific time period (Watson, 1958).

**2.6.6 Yield**

The observations on grain yield, straw yield and biological yield.

**2.7 Statistical Analysis**

The statistical analysis was performed using AGRES software at a 5% significant level of significance.

**3. RESULTS AND DISCUSSION**

**3.1 Leaf Area Index**

The impact of soil amendments with micronutrients on leaf area index of finger millet was depicted in Figure 1. Leaf area index recorded higher with the soil application of Pongamia seed cake @ 1.46 t ha-1 + 100% RDF at 30 DAS and 60 DAS (2.03 and 2.86) and harvest with the Pongamia seed cake @ 1.46 t ha-1 + 100% RDF (4.10) followed by Neem cake @ 1.36 t ha-1 + 100% RDF and lower leaf area index recorded in 100% RDF alone (1.60, 2.1 and 3.02). Nitrification inhibitors reduce the conversion of ammonium nitrogen to nitrate, maintaining a steady supply of ammonium nitrogen for a longer period. This sustained nitrogen availability supports enhanced protein synthesis, chlorophyll production, and cell expansion and increasing LAI reported by Chitte *et al.,* (2016) and Sarkar *et al.* (2011). Among foliar sprays, Fe-EDTA 0.2% @ 30 and 45 DAS had the highest leaf area index at 30 DAS and harvest (2.11 and 3.8), while no spray was the lowest (1.52 and 3.24). At 60 DAS, Fe-EDTA 0.2% @ 30 and 45 DAS high leaf area index of (2.7), followed by Zn-EDTA 0.5% @ 30 and 45 DAS, and No spray were LAI (2.13). According to Das *et al.* (2016) and Meghana *et al.* (2019), the rise in leaf area index (LAI) is due to the plants getting enough iron fortification through foliar during growth stages. This helps the stems and leaves grow longer between nodes and enhances photosynthesis and contributes to overall plant Vigor.

**3.2 Number of leaves**

Figure 2 illustrates the effect of soil amendments and micronutrients foliar application on the number of leaves per plant in finger millet. Soil application of organic amendments significantly increased the number of leaves per plant at different stages of crop 30 DAS, 60 DAS and harvest with Pongamia seed cake @ 1.46 t ha-1 + 100% RDF (13, 21 and 21 leaves) which is remained at par with neem seed cake @ 1.25 t ha-1 + 100% RDF. Lower number of leaves recorded in 100% RDF alone (11, 18 and 18 leaves). Pongamia cake stimulates metabolic processes which promote leaf establish and growth by improving cell division and expansion. This results in more leaves, which enhances attributes of growth and the overall development of the plant reported by Biswas *et al.,* (2023) and similarly reported by Chitte *et al.,* (2016). At 30 DAS, 60 DAS and harvest number leaves per plant significantly increased with the foliar application of Fe-EDTA 0.2% @ 30 DAS and 45 DAS (12, 21 and 21 leaves) which is superior with Zn-EDTA 0.5% @ 30 DAS and 45 DAS and lower number of leaves per plant significantly observed in No spray (11, 18 and 18 leaves) (Fig. 2). Due to the foliar application of micronutrients, particularly iron, Akthar *et al.* (2019) found a significant enhancement in chlorophyll content and leaf growth, leading to improved plant development. Similarly, Setyoningsih *et al.* (2024) reported that the application of Fe-EDTA as a foliar spray increased the availability of Fe2+ in leaves, boosting photosynthesis and growth parameters, including the number of leaves.

**3.3 Stem girth**

Figure 3 depicts the influence of soil amendments and micronutrients foliar application on the stem girth of finger millet. Application of Pongamia seed cake @ 1.46 t ha-1 + 100% RDF increased the stem girth at different stages of crop 30 DAS, 60 DAS and harvest (3.11 mm, 4.28 mm and 3.11 mm). stem girth significantly lower in 100% RDF alone (2.2 mm, 3.17 mm and 2.23 mm). Chitte *et al.* (2016) reported that an ongoing nitrogen supply enhances cambial activity, promoting stem girth development and increasing dry matter production. This suggests a direct correlation between nitrogen availability and structural growth in plants. Foliar application of micronutrient significantly improves the crop growth and stem girth at 30 DAS, 60 DAS and harvest were Fe-EDTA 0.2% @ 30 DAS and 45 DAS (3.01 mm, 3.92 mm and 3.01) and lower stem girth significantly observed in No spray (2.31 mm, 3.49 mm and 2.31 mm). Akhtar *et al.* (2019) found that Fe-EDTA significantly enhanced the bioavailability of Fe2+ in plants, thereby boosting chlorophyll production and enzyme activity, crucial for plant development thus increases the stem girth crucially.

**3.4 Relative growth rate**

Table1 shows the influence of soil amendments and foliar nutrition on relative growth rate. RGR significantly increased at 30 DAS, 60 DAS and harvest by the soil application of Pongamia seed cake @ 1.46 t ha-1 + 100% RDF (0.056 g g-1 d-1, 0.087 g g-1 d-1 and 0.046 g g-1 d-1). Lower RGR significantly reduced in 100% RDF alone (0.049 g g-1 d-1, 0.08 g g-1 d-1 and 0.038 g g-1 d-1). Chitte *et al.,* (2016) noted that Pongamia cake releases essential micro-nutrients, supporting chlorophyll synthesis and enzymatic activities crucial for vegetative growth, which promotes consistent cell division, tiller formation, and dry matter accumulation. Foliar application of micronutrient significantly increased the RGR with Fe-EDTA 0.2% @ 30 DAS and 45 DAS (0.055 g g-1 d-1, 0.084 g g-1 d-1 and 0.044 g g-1 d-1). Lower RGR significantly recorded in No spray (0.05 g g-1 d-1, 0.08 g g-1 d-1 and 0.04 g g-1 d-1). Iron's catalytic role in enzymatic reactions, hormone production, and protein synthesis facilitated cell division and metabolic activity, thereby promoting sustained growth, as similarly observed by Baishya *et al.* (2016).

**3.4 Net assimilation rate**

The impact of soil amendments and foliar nutrition on the net assimilation rate is displayed in Table 1. There is a significant increased NAR at 30, 60 DAS and harvest with the Pongamia seed cake @ 1.46 t ha-1 + 100% RDF (0.075g m-2 d-1, 0.024 g m-2 d-1 and 0.0049 g m-2 d-1). Significantly lower NAR recorded in Pongamia seed cake @ 1.46 t ha-1 + 100% RDF (0.059 g m-2 d-1and 0.016 g m-2 d-1). Similarly, Paramasiva *et al.* (2020) noted that Pongamia cake releases essential micro-nutrients, supporting chlorophyll synthesis and enzymatic activities crucial for vegetative growth. It doesn’t show any significant in improvement on NAR at 30DAS. No spray significantly increased the NAR at 60 DAS with Fe-EDTA 0.2% @ 30 DAS and 45 DAS (0.2 g m-2 d-1) significantly lower NAR recorded in No spray (0.019 g m-2 d-1). There is no significant observation on NAR at harvest. It is due to the application of Fe-EDTA significantly enhanced RGR by increasing chlorophyll synthesis and photosynthetic efficiency, leading interception of photosynthetically active radiation and higher dry matter accumulation, as reported by Das *et al.* (2016) and Rakesh *et al.* (2012).

**3.5 Yield**

Figure 4 illustrates the effect of soil amendments and micronutrients foliar application on the yield of finger millet. Grain yield is significantly increased by the application of soil organic amendments with Pongamia seed cake @ 1.46 t ha⁻¹ + 100% RDF were 2891 kg ha-1 superior with Neem seed cake @ 1.25 t ha⁻¹ + 100% RDF, lower grain yield recorded in 100% RDF alone of 1246 kg ha-1. By minimizing nitrogen losses and providing a slow release and increased nutrient absorption, nitrification inhibitors increase photosynthetic efficiency, dry matter, and yield. The findings are consistent with those of Osmon *et al.* (2009), Biswas *et al.* (2023), and Chitte *et al.* (2016). Foliar application of micronutrient significantly increased the grain yield with Fe-EDTA 0.2% @30 & 45 DAS of 2729 kg ha-1 and low recorded in No spray in 2188 kg ha-1. According to Meghana *et al*. (2019) and Bhatti *et al.* (2024), foliar feeding increases the crop's nutrition availability at the right moment, improves cell division, and increases physiological processes.

Soil application of organic amendments significantly increased the straw yield with Pongamia seed cake @ 1.46 t ha⁻¹ + 100% RDF of 5752 kg ha-1 and lower straw yield observed in 100% RDF alone of 4203 kg ha-1. Organic amendments stimulate active soil microflora, promoting the flow of nutrients and suppressing pathogens, thus lowering disease pressure triggering enhanced plant growth, yielding an enhanced straw yield, as stated by Barnwal *et al*. (2007). Foliar application of micronutrient significantly increased the straw yield with Fe-EDTA 0.2% @30 & 45 DAS were 5367 kg ha-1 followed by Zn-EDTA 0.5% @30 & 45 DAS with 5350 kg ha-1 while lower straw yield observed in No spray of 4695 kg ha-1. Fe-EDTA foliar spray increases straw yield through increased iron uptake at a faster rate, enhancing photosynthesis, chlorophyll content, and metabolic activities, leading to increased plant growth (Vikashkumar *et al.,* 2015).

**4. CONCLUSION**

The study concluded that soil application of with Pongamia seed cake @ 1.46 t ha⁻¹ + 100% RDF significantly enhanced growth parameters, including leaf area index, number of leaves, stem girth, relative growth rate, and net assimilation rate. This treatment also achieved the highest grain and straw yields. Foliar application of Fe-EDTA 0.2% @30 & 45 DAS at critical growth stages further improved growth attributes and resulted in increased grain and straw yields. These treatments outperformed neem seed cake combined with RDF and other foliar sprays, highlighting the synergistic benefits of organic amendments and micronutrient foliar applications in improving plant growth and yield under calcareous soil conditions.

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**Table 1: Effect of soil amendments and foliar nutrition on relative growth rate, net assimilation rate of finger millet**

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| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Relative growth rate (g g-1 day -1)** | | | **Net assimilation rate (g m-2 day-1)** | | |
|  | **0-30 DAS** | **30-60 DAS** | **60 DAS - Harvest** | **0-30 DAS** | **30-60 DAS** | **60 DAS -Harvest** |
| **Soil amendments (S)** |  |  |  |  |  |  |
| S1- Pongamia seed cake @ 1.46 t ha-1 +100 %RDF | 0.056 | 0.087 | 0.046 | 0.075 | 0.024 | 0.0049 |
| S2- Neem seed cake @ 1.25 t ha-1 + 100 % RDF | 0.052 | 0.085 | 0.042 | 0.067 | 0.019 | 0.0047 |
| S3- Castor seed cake @ 1.45 t ha-1 + 100 % RDF | 0.051 | 0.081 | 0.042 | 0.062 | 0.018 | 0.0047 |
| S4- FYM @ 12.5 t ha-1 + 100 % RDF | 0.050 | 0.080 | 0.040 | 0.059 | 0.018 | 0.0044 |
| S5- 100 % RDF alone (Control) | 0.049 | 0.080 | 0.038 | 0.059 | 0.016 | 0.0045 |
| Sed | 0.001 | 0.001 | 0.001 | 0.003 | 0.001 | 0.0002 |
| CD (P=0.05%) | 0.002 | 0.003 | 0.002 | 0.005 | 0.002 | NS |
| **Foliar nutrition (F)** |  |  |  |  |  |  |
| F1- Fe-EDTA 0.2% @ 30 and 45 DAS | 0.055 | 0.084 | 0.044 | 0.066 | 0.02 | 0.0048 |
| F2- Zn-EDTA 0.5% @ 30 and 45 DAS | 0.052 | 0.083 | 0.041 | 0.065 | 0.02 | 0.0047 |
| F3- Mn-EDTA 0.5% @ 30 and 45 DAS | 0.051 | 0.083 | 0.041 | 0.063 | 0.017 | 0.0046 |
| F4- No spray (Control) | 0.05 | 0.08 | 0.04 | 0.062 | 0.019 | 0.0044 |
| Sed | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | 0.0021 |
| CD (P=0.05%) | 0.002 | 0.003 | 0.002 | NS | 0.002 | NS |

Level of significance at 5%, DAS- Days After Sowing, RDF- Recommended Dose of Fertiliser, EDTA- Ethylene Diamine Tetraacetic Acid

**Fig.1 Effect of soil organic amendments and micronutrients foliar on leaf area index of finger millet**

**Fig.2 Effect of soil organic amendments and micronutrients foliar on number of leaves per plant of finger millet**

**Fig.3 Effect of soil organic amendments and micronutrients foliar on stem girth (mm) of finger millet**

**Fig.4 Effect of soil organic amendments and micronutrients foliar on grain yield (kg ha-1) and straw yield (kg ha-1) of finger millet.**