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# Assessing the Nutrient Availability of Rice Grown Coastal Sandy Soils and Mineralization Potential of a Solid Formulation Developed for the Region

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## Abstract

The growth and development of crops in the coarse textured northern coastal plain are predominantly affected by imbalanced nutrition leading to deficiencies of the secondary and micronutrients. The present study aimed to evaluate the performance of a solid formulation, named *ayar* - a secondary and micronutrient mixture developed by us for rice crop after assessing the fertility of coarse sandy soils. The soils of the northern coastal plains were deficient in available calcium, magnesium, zinc and boron whereas the availability of soil sulphur was sufficient. The developed *ayar* nutrient mixture for rice contains calcium (15%), magnesium (7.6%), sulphur (2%), zinc (1.75%) and boron (0.75%). The current research focused on understanding the release of various nutrients into the soil over a period of four months when applied in varied doses under water logged conditions. The results revealed that application of *ayar* mixture at a dose of 30 kg/ha released the maximum amount of available calcium, magnesium, sulphur, zinc and boron in the soil. It has increased the levels of available calcium (140%), magnesium (47.2%), sulphur (57.8%), zinc (71.7%) and boron (42.8%). The application of *ayar* mixture containing secondary and micronutrients could be a promising nutrient supplement for rice grown in coarse textured northern coastal soils.

*Keywords* : *Ayar* nutrient mix, Mineralization potential, Secondary and micro nutrient mix

Essential nutrients, particularly secondary and micronutrients play an important role in the growth and development of crops. Calcium plays a crucial role as a secondary nutrient in plant development, ensuring structural stability, cell wall integrity and signal transmission (Hazarika and Kumar, 2020). Magnesium plays critical roles in plant physiology such as central component of chlorophyll, capturing solar energy and cofactor for over 300 enzymes, including carboxylases and ATPases (Hawkesford *et al*., 2012). Sulphur is important for the synthesis of amino acids like cysteine and methionine. Boron facilitates sugar transport by forming complexes, enabling movement through cell membranes (Marschner, 1995). It also promotes pollen tube growth, influencing fruit development. Zinc plays a vital role in plant development, influencing enzyme activity, protein configuration, membrane integrity and resistance to oxidative stress. The coarse textured sandy soils in the northern coastal plains have evidenced significant deficiencies of the secondary and micronutrient in them due to the prevailing climatic conditions and the soil textural properties.

Rice crop has specific nutrient requisites that are vital for its adequate growth and development. The attempt for physiological understanding of rice nutrition revealed the emphasis of balanced fertilization to achieve optimum yields, especially for high yielding varieties that require more fertile soil environment (Ishizuka, 1971). Hence, catering both macro and micronutrient needs are essential for maximizing rice production and combating malnutrition in populations reliant on the staple crop (Loneragan, 1968). The growth of crops in the sandy soil was remarkably affected due to the deficiency of certain secondary and micronutrients. In this context, present study was planned to evaluate the status of available nutrients in northern coastal soils and assessing the suitability of a secondary and micronutrient mixture – *ayar*, developed for rice crop to serve the purpose of mitigating the nutrient deficiency in the soil. A preliminary incubation study was conducted to visualize its effectiveness in a coarse sandy soil.

## Material and Methods

Soil samples were collected from 25 different locations of the northern coastal plain region where rice crop was cultivated. The collected soil samples from a depth of 0-20 cm were put into clean polythene bags and neatly labelled. The samples were transferred to the laboratory and air dried, then sieved in a 2 mm sieve for conducting further analysis. Available nitrogen estimation followed alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus was extracted using Bray No. 1 solution and estimated using spectrophoto meter (Bray and Kurtz, 1945), the extraction of available potassium was done by neutral normal ammonium acetate and estimated using the flame photometer (Jackson, 1958), the available calcium and magnesium was also extracted using neutral normal ammonium acetate, then estimated by complexometric titration (Goldstein, 1959), available sulphur followed calcium chloride extraction followed by estimation using spectrophotometer (Mossoumi and Cornfield, 1963), micronutrients like iron and zinc was extracted by 0.1 N HCl and estimated using atomic absorption spectrophotometer (Sims and Johnson, 1991), the available boron estimation followed Azomethane H method (Gupta, 1972).

A solid formulation named *ayar* – a secondary and micronutrient mixture was developed by physical blending commercially available fertilizers by trial and error method. The formulation was checked for its nutrient content and quality and durability.

The mineralization potential of the solid formulation named as *ayar* nutrient mixture which contained calcium, magnesium, sulphur, zinc and boron was analyzed by carrying out an incubation study with the soil collected from arice growing region of the northern coastal plains after assessing the available nutrients of different locations and selecting an area with lowest micronutrient availability and filled in pots. The soil pH of this region was 5.35. Each pot contained 5 kg of soil and different doses of mixture were applied as treatments. The treatments imposed included $T_1$ (absolute control), $T_2$ (*ayar* at 20 kg ha$^{-1}$), $T_3$ (*ayar* at 25 kg ha$^{-1}$) and $T_4$ (*ayar* at 30 kg ha$^{-1}$). The pots were maintained at water logged conditions and the observations were taken at an interval of 30 days for a period of 120 days. Watering was done regularly to maintain submergence. The soils from the pots were collected at monthly intervals and were analyzed for available calcium and magnesium, available sulphur, available zinc and available boron.

The data was statistically analyzed following the approach described by Fisher and Yates (1958) sing GRAPES software (Gopinath *et al*., 2020). The significance of the treatment effects was evaluated by comparing the F values among the treatment means, along with the critical difference (C.D) and the standard error of the mean.

## Results and Discussion

Table 1 presents the results of the soil chemical analysis. Available nitrogen levels in this region ranged from 150.2 to 288.51 kg/ha. Soil phosphorus levels varied between 32.06 and 92.72 kg P/ha, with an average of 49.92 kg P/ha.Soil potassium levels ranged from 18.7 to 135.52 kg K/ha. Considering secondary nutrients, the mean calcium level was 280.8 ppm, with values ranging from 160 to 380 ppm. Soil magnesium ranged from 84 to 156 ppm, averaging 124.8 ppm, while sulphur levels were between 15.16 and 81.13 ppm, with a mean of 55 ppm. Among the micronutrients, available iron showed a mean of 59.44 ppm, available zinc averaged 0.65 ppm and available boron had a mean value of 0.38 ppm. The ranges were 24.8 to 94.2 ppm for available iron, 0.216 to 0.936 ppm for available zinc and 0.024 to 1.362 ppm for available boron.

**TABLE 1**

**Status of the nutrients in the northern coastal plains**

| Parameter | Soil range | Mean ± SE (m) |
|---|---|---|
| Nitrogen (kg $ha^{-1}$) | 150.2 – 288.51 | 226.74 ± 7.9 |
| Phosphorus (kg P $ha^{-1}$) | 32.06 – 92.72 | 49.92 ± 3.71 |
| Potassium (kg K $ha^{-1}$) | 18.7 – 135.52 | 71.118 ± 7.38 |
| Calcium (ppm) | 160 – 380 | 280.8 ± 11.34 |
| Magnesium (ppm) | 84 – 156 | 124.8 ± 4.38 |
| Sulphur (ppm) | 15.16 – 81.13 | 55 ± 4.12 |
| Iron (ppm) | 24.8 – 94.2 | 59.44 ± 3.28 |
| Zinc (ppm) | 0.216 – 0.936 | 0.65 ± 0.03 |
| Boron (ppm) | 0.024 – 1.362 | 0.38 ± 0.06 |

A detailed investigation into nutrient availability across 25 locations in coastal sandy soils revealed that most soils were deficient in available nitrogen. Kerala's soils, which are highly weathered with low cation exchange capacity, a predominance of low-activity clays and acidic pH, are nutrient-poor due to heavy rainfall patterns that result in nutrient leaching (GOK, 2019). Sumfleth and Duttmann (2008) noted an inverse relationship between soil nitrogen content and sand content, and low nitrogen levels have been specifically reported in Kerala's southern coastal soils (Athulya *et al*., 2023).

In terms of available phosphorus content, levels ranged from 32.06 to 92.72 kg P/ha, indicating no deficiency. The observed phosphorus accumulation is likely due to repeated use of phosphatic fertilizers (Vinutha *et al*, 2010) and the low mobility of phosphate ions (Thuy*et al*., 2020). Without soil testing, continued excessive application of phosphatic fertilizers could lead to nutrient toxicity, causing soil and water pollution.

Majority of samples indicated potassium deficiency, as the low clay and buffering capacity of sandy soils allow $K^+$ ions to leach easily (Kolahchi and Jalali, 2007). Even with potassium fertilizer application, the increase in potassium remains temporary. Jhonston and Goulding (1992) observed that 100 mm of rainfall could leach out approximately 1 kg $K^+$ per hectare. Of the 25 samples analyzed, 16 samples showed deficiency in available calcium, which can be attributed to leaching in light-textured soils (Chandrakala *et al*., 2018). Calcium availability is further reduced in acidic soils (Rahman, 2018), affecting the uptake of other nutrients and inhibiting root growth.

About 52 per cent of the samples were deficient in magnesium, likely due to parent materials in the region being iron-rich and magnesium-poor, combined with magnesium leaching due to climatic conditions (Senbayram *et al*., 2015). Sulphur deficiency was not observed, as the acidic nature of the soil aids in sulfur retention, consistent with findings by Athulya *et al*. (2023). Iron levels were found to be sufficient, with concentrations above 5 ppm. High iron content in the soil likely results from iron-rich parent materials and acidic conditions that facilitate nutrient release (Nair *et al*., 2018). However, presence of excessive iron can impair the uptake of other nutrients, reducing rice productivity by 12-100 per cent (Sahrawat, 2005).

Soils with available zinc levels below 1 ppm are considered deficient (DOA, 2013) and 100 per cent of the samples showed zinc deficiency. High phosphorus levels, which have an antagonistic relationship with zinc, could explain this deficiency (Mousavi, 2011). The acidic nature of the soil also reduces the zinc availability (Kumar *et al*., 2010). Across India, zinc deficiency is reported in nearly 39 per cent of soils (Khokhar *et al*., 2024). Zinc deficiency affects not only plant health but also human health, potentially leading to stunted growth in human beings (Bevis *et al*., 2023). About 92 per cent of soil samples were deficient in available boron, which could be due to the leaching and mobility of boron in coarse-textured soils (Nair *et al*., 2018).

*The Developed Solid Formulation* : *ayar* was a secondary and micronutrient mixture formulated by the College of Agriculture, Padannakkad, Kerala for meeting the nutrient requirements of rice growing coarse sandy soils on the basis of soil test values. The nutrient status of the rice growing soils of the northern coastal plains suggest that they were deficient in the soil availability of calcium, magnesium, zinc and boron whereas the concentration of available sulphur was sufficient. With this data the *ayar* nutrient mix was standardized to make it suitable for achieving balanced fertilization in rice plants as rice is the major crop grown in coastal soils. The formulated *ayar* nutrient mix had a composition of calcium (15%), magnesium (7.6%), sulphur (2%), zinc (1.75%) and boron (1%). Before field application to rice plants, it is necessary to study the mineralization potential of *ayar* nutrient mix in soil application to assess its behaviour in soil and its impact on soil properties.

The soil analytical data after application of treatments showed that available nutrients exhibited varying levels across treatments and months of incubation study. With respect to available calcium (Table 2), treatment $T_4$ consistently exhibited the highest values, with 532 mg/kg in the first month, 472 mg/kg in the second, 548 mg/kg in the third and 588 mg/kg in the fourth month and the least values were observed in control $T_1$. The results are given in Fig. 1. The elevated available calcium levels in $T_4$ (*ayar* at 30 kg ha$^{-1}$) can be attributed to the increased dosage of *ayar* nutrient mix which supplies maximum calcium content to the soil. Further more, the synergistic relationship between calcium and magnesium enhances calcium availability in soil (Lange *et al*., 2021). The initial status of the available calcium in the soil was deficient (240 mg/kg). The treatment $T_1$ experienced an increase of 25 per cent in the calcium content during the first and second month, in the third month the increase was about 38.3 per cent and in the last month the increase was only about 1.6 per cent on comparing the third and fourth month about 26.5 per cent reduction in the available calcium level in treatment $T_1$ was observed. In case of treatment $T_2$, the increase in available calcium when compared to initial value

**TABLE 2**

**Effect of ayar nutrient mix on soil available calcium during incubation study**

| Treatments | Available calcium (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | First month | Second month | Third month | Fourth month |
| $T_1$ | 300 $^{a}$ | 300 $^{c}$ | 332 $^{b}$ | 244 $^{c}$ |
| $T_2$ | 384 $^{b}$ | 360 $^{bc}$ | 368 $^{b}$ | 412 $^{b}$ |
| $T_3$ | 368 $^{b}$ | 400 $^{ab}$ | 364 $^{b}$ | 528 $^{a}$ |
| $T_4$ | 532 $^{b}$ | 472 $^{b}$ | 548 $^{a}$ | 588 $^{a}$ |
| SE (m+) | 31.559 | 27.313 | 30.199 | 32.125 |
| CD (0.05) | 94.615 | 81.884 | 90.538 | 96.31 |

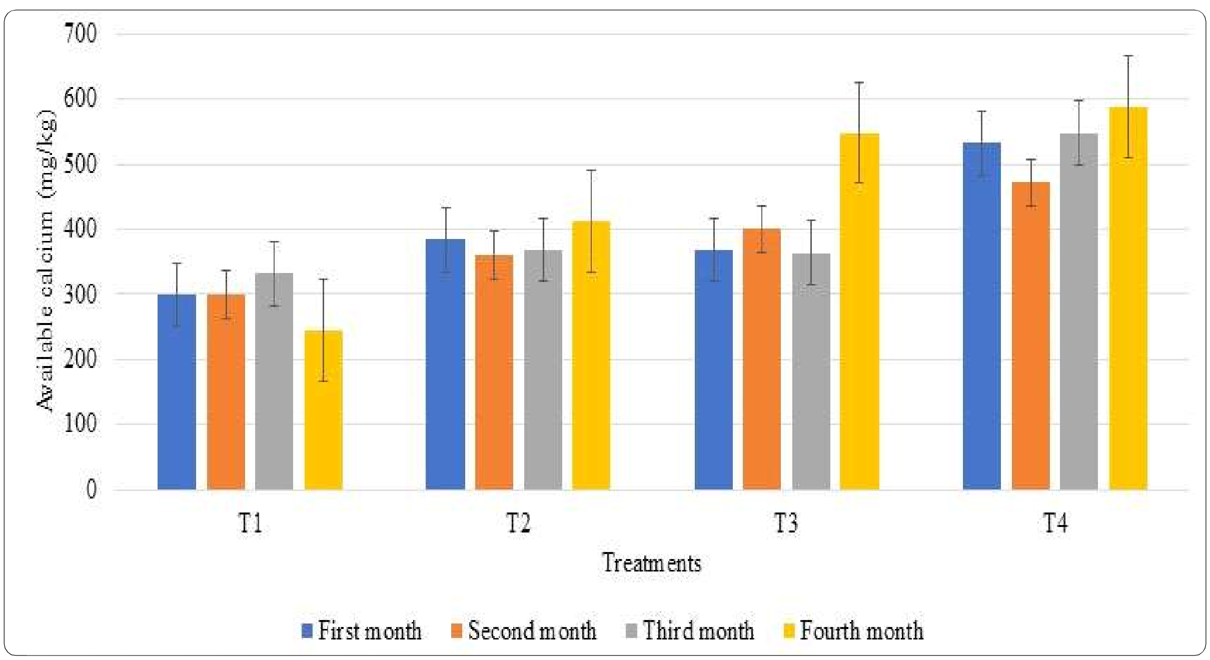


Fig. 1 : Effect of ayar nutrient mix on soil available calcium during incubation study

was 60, 50, 53.3, 71.6 per cent for the respective months. An increase of about 53.3 per cent was observed in case of treatment $T_3$ during the first month and in the following 3 months the increase was 66.7, 51.6, 120 per cent respectively. Treatment $T_4$ showcased an increase of about 121.6, 96.6, 128.5, 145 per cent in the first, second, third and fourth month respectively. In comparison to control, the increase in the available calcium content in the soil during the fourth month for different treatments wherein the application of *ayar* nutrient mix were applied, was 68.8% for $T_2$, 116 per cent for $T_3$ and 140 per cent for $T_4$. (Table 7) The results provide a positive indication that application of ayar nutrient mix could enhance the calcium availability in soil with time.

The results of available magnesium (Table 3), for the first month, indicated that highest value was observed in treatment $T_3$ (182.4 mg/kg) and the lowest value in treatment $T_4$ (124.8 mg/kg). In the second month, treatment $T_4$ had recorded the highest level at 223.2 mg/kg, while treatment $T_3$ was lowest at 156.0 mg/kg. The results of third month showed no significant difference among treatments, with levels ranging from 165.6 mg/kg in $T_2$ to 208.8 mg/kg in $T_3$. In the fourth month, treatment $T_2$recorded highest content with a value of 268.8 mg/kg, tied with treatments $T_3$ and $T_4$, while treatment $T_1$ trailed at 172.8 mg/kg (Fig 2). The study findings indicate that applying varying doses of *ayar* nutrient mix over time significantly impacted magnesium release in soil. Combining calcium and boron supplements enhanced magnesium availability, supporting previous research (Wang *et al*., 2015). The initial level of available magnesium in the soil was 84 mg/kg. In treatment $T_1$, available magnesium content rose by 43.5 per cent in the first

TABLE 3

**Effect of ayar nutrient mix on soil available magnesium during incubation study**

| Treatments | Available magnesium (mg kg-1) | | | |
|---|---|---|---|---|
| | First month | Second month | Third month | Fourth month |
| $T_1$ | 148.8 [ab] | 163.2 [b] | 175.2 | 172.8 [b] |
| $T_2$ | 146.4 [ab] | 168.0 [b] | 165.6 | 268.8 [a] |
| $T_3$ | 182.4 [a] | 156.0 [b] | 208.8 | 249.6 [a] |
| $T_4$ | 124.8 [b] | 223.2 [a] | 199.2 | 254.4 [a] |
| SE (m+) | 12.296 | 16.01 | 13.309 | 16.432 |
| CD (0.05) | 36.864 | 47.998 | NS | 49.262 |

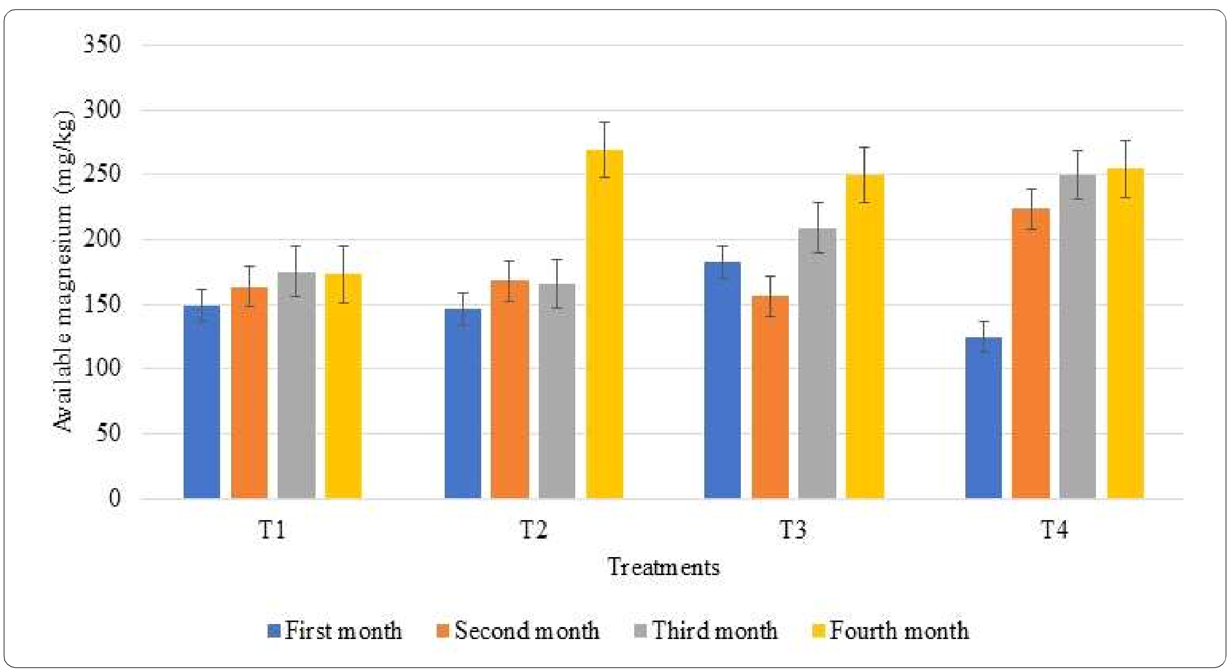


Fig. 2 : Effect of ayar nutrient mix on soil available magnesium during incubation study

month, 94.2 per cent in the second and 108.5 per cent in the third. However, there was a slight decrease of 1.36 per cent between the third and fourth months, with the fourth month showing a total increase of 105.7 per cent from the starting level. For treatment $T_2$, the increases in available magnesium compared to the initial level were 74.2, 100, 97.2 and 220 per cent across the four months, respectively. Treatment $T_3$exhibited 117 per cent increase in the first month, followed by increases of 85.7, 148.5 and 197.1 per cent in the subsequent months. Treatment $T_4$ exhibited increases of 48.5, 165, 137 and 202 per cent across the four months. By the fourth month, when compared to the control, the application of *ayar* nutrient mix resulted in available magnesium content increase of 55.5 per cent for $T_2$, 44.4 per cent for $T_3$, and 47.2 per cent for $T_4$(Table 7).

The available sulphur in the soil during the incubation study is given in Table 4. In the first month, with respect to available sulphur, treatment $T_4$ exhibited the highest value at 22.076 mg S/kg, while control $T_1$ had recorded the lowest at 8.754 mg S/kg. During the second month, treatment $T_2$ reached the maximum value of 23.180mg S/kg, comparable to treatment $T_4$ (21.500mg S/kg) and treatment $T_1$ recorded the lowest value (14.872 mg S/kg). In the third month, treatment $T_4$ again recorded the highest value at 28.158 mg S/kg statistically similar to treatments $T_2$ (26.222 mg S/kg) and $T_3$ (24.428 mg S/kg), while treatment $T_1$ remained the lowest at 15.608 mg S/kg. By the fourth month, treatment $T_4$ (32.872 mg S/kg) showed maximum value, comparable to treatment $T_2$ and treatment $T_1$ showing the lowest value (Fig 3). The enhanced release of available sulphur in soil may be attributed to slight improvement of soil pH, caused by addition of calcium and magnesium, which in turn

TABLE 4

**Effect of ayar nutrient mix on soil available sulphur during incubation study**

| Treatments | Available sulphur (mg S kg$^{-1}$) | | | |
|---|---|---|---|---|
| | First month | Second month | Third month | Fourth month |
| $T_1$ | 8.754 $^d$ | 14.872 $^c$ | 15.608 $^b$ | 20.830 $^c$ |
| $T_2$ | 12.250 $^c$ | 23.180 $^a$ | 26.222 $^a$ | 29.234 $^{ab}$ |
| $T_3$ | 14.730 $^b$ | 17.872 $^{bc}$ | 24.428 $^a$ | 27.148 $^b$ |
| $T_4$ | 22.076 $^a$ | 21.500 $^{ab}$ | 28.158 $^a$ | 32.872 $^a$ |
| SE (m+) | 0.611 | 1.644 | 1.3 | 1.489 |
| CD (0.05) | 1.831 | 4.93 | 3.899 | 4.463 |

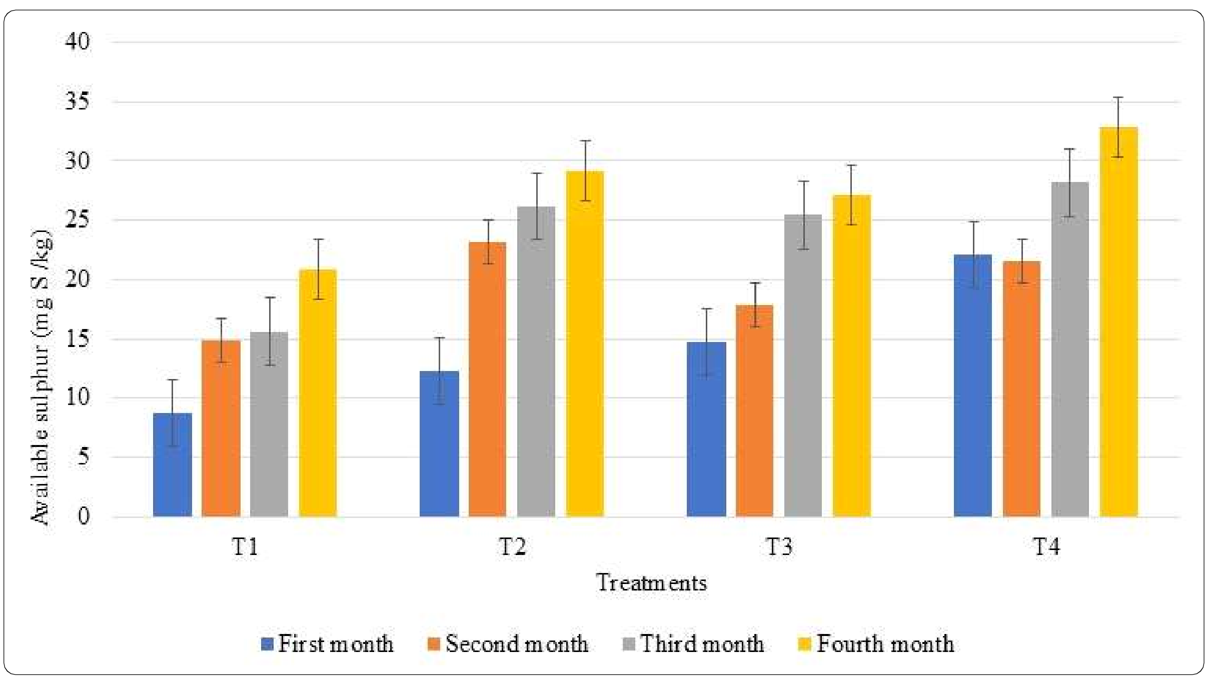


Fig. 3 : Effect of ayar nutrient mix on soil available sulphur during incubation study

increases sulphur availability. Studies suggest that increased pH levels in sandy soils further increased sulphur availability (Azman *et al*., 2023). The initial status of available sulphur in the soil was 23.2 mg S / kg. when compared to the initial available sulphur content in the soil treatment $T_1$ (absolute control) experienced a decrease of 62.2 per cent in the available sulphur content during the first month, during the second month the decrease was about 35.9 per cent. In the third month the decrease was about 32.7 per cent and in the last month the decrease was about 10 per cent. In case of treatment $T_2$, which received *ayar* mixtureat 20 kg $ha^{-1}$ showed an increase in available sulphur content when compared to the control as 40 per cent during the first month and there was an increase in the available sulphur content during the second (55.8%) third (67.9) and fourth (40.32%) month. Comparing with the control an increase of about 68.34 per cent was observed in case of treatment $T_3$ during the first month and in the second month and the increase of about 20.17 per cent during the following months had recorded an increase of about 56.5 and 30.34 per cent respectively. With respect to the control the treatment $T_4$ exhibited an increase of 152.2 per cent during the first month and the following months had an increase of 44.58, 80.39 and 57.8 per cent respectively. The sulphur content showed varying trends throughout the incubation study. The initial content of available sulphur in the experiment soil was high which might be attributed to the sulphur containing minerals present in the acid soils (Golez and Kyuma, 1997). The application of *ayar* nutrient mixture caused a slight enhancement in sulphur contents but the effect was not pronounced throughout the period of incubation study.

In the incubation study, available zinc (Fig 4), was found non-significant among the treatments during the first and second months. In the third month, treatment $T_4$ recorded the highest value at 7.904 mg/kg, which was comparable to treatments $T_3$ (7.488 mg/kg) and $T_2$ (7.220 mg/kg), while treatment $T_1$ had recorded the lowest value. In the fourth month, treatment $T_4$ again had the highest value and treatment $T_1$ had the lowest available zinc content (Table 5). The increased availability of zinc in the soil may be attributed to the application of zinc-containing fertilizers. These findings can be compared to those of Xiao (2005). The initial status of the available zinc in the soil was 6.78 mg/kg. The treatment $T_1$ experienced a decrease in available zinc content of about 2 per cent during the first month. In the second and third month the decrease was about 6.6 per cent

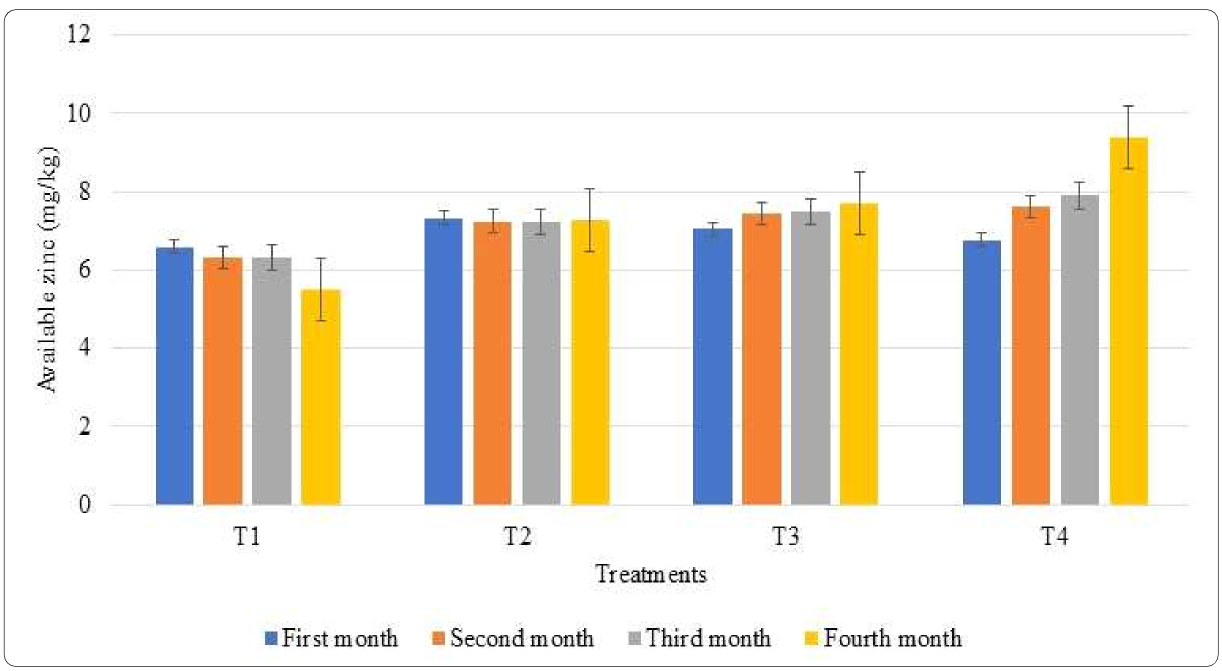


Fig. 4 : Effect of ayar nutrient mix on soil available zinc during incubation study

**TABLE 5**

**Effect of ayar nutrient mix on soil available zinc during incubation study**

| Treatments | Available zinc (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | First month | Second month | Third month | Fourth month |
| $T_1$ | 6.598 | 6.334 | 6.334 $^{b}$ | 5.484 $^{c}$ |
| $T_2$ | 7.332 | 7.246 | 7.220 $^{ab}$ | 7.282 $^{b}$ |
| $T_3$ | 7.042 | 7.440 | 7.488 $^{a}$ | 7.694 $^{b}$ |
| $T_4$ | 6.768 | 7.628 | 7.904 $^{a}$ | 9.378 $^{a}$ |
| SE (m+) | 0.522 | 0.455 | 0.357 | 0.479 |
| CD (0.05) | NS | NS | 1.069 | 1.435 |

**TABLE 6**

**Effect of ayar nutrient mix on soil available boron during incubation study**

| Treatments | Available boron (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | First month | Second month | Third month | Fourth month |
| $T_1$ | 0.512 $^{b}$ | 0.489 $^{c}$ | 0.492 $^{c}$ | 0.493 $^{b}$ |
| $T_2$ | 0.514 $^{b}$ | 0.529 $^{c}$ | 0.538 $^{bc}$ | 0.552 $^{b}$ |
| $T_3$ | 0.580 $^{a}$ | 0.587 $^{b}$ | 0.617 $^{ab}$ | 0.637 $^{a}$ |
| $T_4$ | 0.614 $^{a}$ | 0.644 $^{a}$ | 0.692 $^{a}$ | 0.699 $^{a}$ |
| SE (m+) | 0.024 | 0.017 | 0.021 | 0.018 |
| CD (0.05) | 0.073 | 0.052 | 0.064 | 0.054 |

and in the last month the decrease was about 19 per cent. In case of treatment $T_2$, the increase in available zinc when compared to initial value was 8.1 per cent in the first month, 6.87 per cent in the second month, 6.48 per cent in the third month and 7.40 per cent in the fourth month. This showed that application of *ayar* mixture at 20 kg/ha was not sufficient to enhance available zinc in sandy soil. The concentration of available zinc in the treatment $T_3$ was increased by 3.85 in the first month and in the following 3 months the increase was 9.1, 10.4, 13.5 per cent respectively. Treatment $T_4$ showcased an increase of about 12.3, 16.5 and 38.3 per cent in the second, third and fourth month respectively. When compared to the control the increase in the available zinc content in the soil during the fourth month for different treatments with application of *ayar* mixture, was recorded as 32.1 per cent for $T_2$, 40.3 per cent for $T_3$ and 38.3 per cent for $T_4$. With respect to available zinc, *ayar* mixture of 25 kg/ha and 30 kg/ha was found performing well under a sandy soil environment.

The results of the available boron are given in Table 6. During the first month, the highest availability of boron in the soil was found in treatment $T_4$ (0.614 mg/kg) which was on par with treatment $T_3$ (0.580 mg/kg), while treatment $T_1$ had recorded the lowest (0.512 mg/kg). In the second month, treatment $T_4$ again recorded the maximum value and treatment $T_1$ had been showing the lowest value. By the third month, the highest value was registered in the same treatment $T_4$ (0.692 mg/kg), while treatment $T_1$ had recorded the least value. In the fourth month a similar trend was followed with treatment $T_4$ having the highest value and $T_1$ had the lowest value (Fig 5). The significant differences in soil boron availability may be attributed to the application of boron fertilizers. These findings can be compared with those of Dunn *et al*., (2005). The available boron in the soil initially measured 0.43 mg/kg. Over four months, different treatments showed varying increments. Treatment $T_1$ evidenced a 18.6 per cent increase in the first month, followed by 13.9 per cent increments. Treatment $T_2$ had recorded increase of 18.6, 23.2, 23.2 and 27.9 per cent over the four months. Treatment $T_3$ showed a 34.8 per cent increase initially, followed by 37.2, 41.8 and 46.5 per cent in the next three months. Treatment $T_4$ had an increase in the available boron about 41.8, 48.8, 60.4 and 62.7 per cent in the four months respectively. Compared to the control, treatments $T_2$, $T_3$ and $T_4$ showed 12.2, 28.5 and 42.8 per cent increases in available boron (Table 7) after four months, respectively, following the application of *ayar* mixture for enhancement of boron availability in coarse sandy soils.

The results of soil chemical analysis, indicated that soils were deficient in calcium, magnesium, zinc and boron whereas the sulphur content of the soil was sufficient. The availability of nitrogen and potassium was also deficient. The results of the incubation study

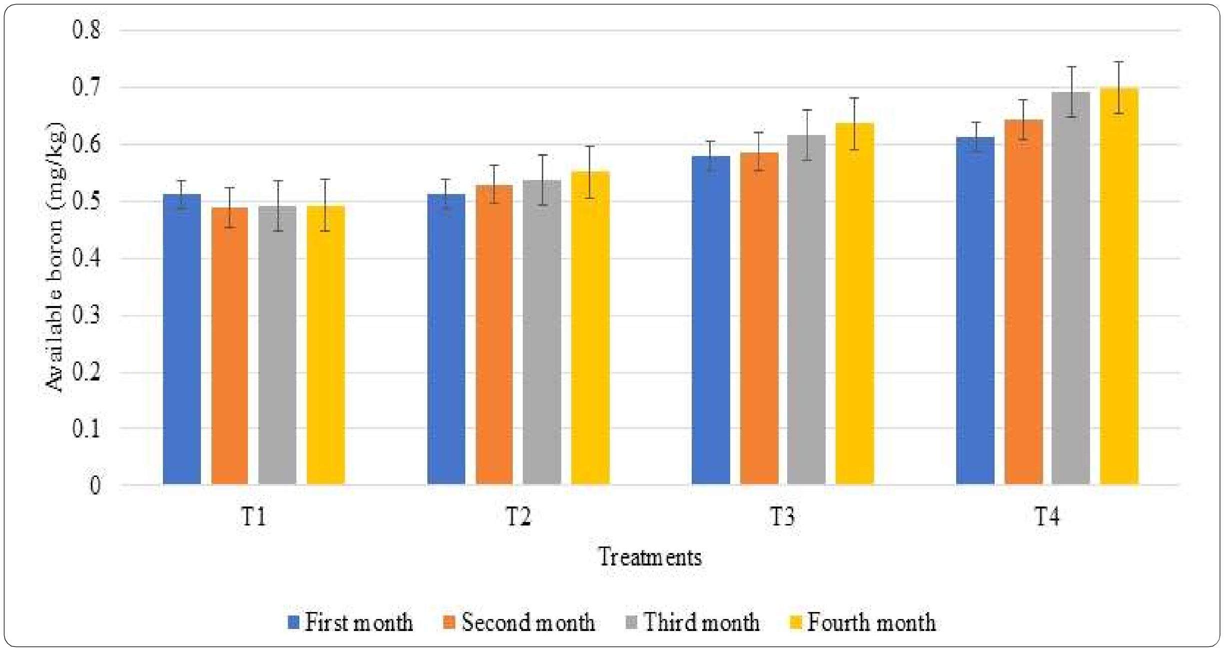


Fig. 5 : Effect of ayar nutrient mix on soil available boron during incubation study

**TABLE 7**

**Percentage increase in the available nutrients in comparison to the control during fourth month**

| Treatments | % increase in available calcium | % increase in available magnesium | % increase in available sulphur | % increase in available zinc | % increase in available boron |
|---|---|---|---|---|---|
| $T_2$ | 68.8 | 55.5 | 40.32 | 32.1 | 12.2 |
| $T_3$ | 116 | 44.4 | 30.34 | 40.3 | 28.5 |
| $T_4$ | 140 | 47.2 | 57.8 | 38.3 | 42.8 |

revealed that treatment $T_4$ (*Ayar* at 30 kg/ha) consistently demonstrated superior levels of available calcium, sulphur and boron in all months whereas zinc showed maximum levels in the same treatment during the last two months. Available magnesium showed best results with treatment $T_3$, $T_4$ and $T_2$ in the first, second and fourth month respectively. While comparing the control with the best treatment ($T_4$) the increase in the availability of various nutrients were calcium 140 per cent, magnesium 47.2 per cent, sulphur 57.8 per cent, zinc (71.7%) and boron (42.8%). So, the application of this *ayar* nutrient mixture in the sandy soil can improve the availability of calcium, magnesium, sulphur, zinc and boron.

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