*__Original Research Article__*

# Fortified Organic Manure and NPK fertilizer levels: Influence on Soil Properties, Yield and Micronutrients Biofortification of Brinjal in Coastal Soil


## ABSTRACT

Coastal saline soils are nutrient impoverished and in such nutrient starved condition increased rate of NPK along with micronutrients fortified organics would greatly improve the soil fertility as well as nutritional quality and yield of brinjal. Therefore, this study was taken up to find out the effect of micronutrients fortified organics and NPK levels on the soil properties, yield and quality of brinjal in coastal saline soil. A field experiment was conducted at Ponnanthittu coastal village, near Chidambaram, Cuddalore district, Tamil Nadu during August – December 2022 in sandy saline soil (EC-1.58 $dSm^{-1}$; pH-8.54) nature with low organic carbon (2.31 g $kg^{-1}$), available NPK of 135.56, 9.45 and 157.30 kg $ha^{-1}$ and the available zinc (0.69 mg $kg^{-1}$) and iron content (3.87 mg $kg^{-1}$). The treatments adopted in a Factorial Randomized Block Design (FRBD) with three replications and different levels of NPK *viz.*, control, 100, 125 and 150% recommended levels as factor A and different micronutrients fortified organics viz., 100% Zn Fortified Composted Coir pith (ZnFCCP) @ 6.25 t $ha^{-1}$), 100% Fe Fortified Composted Coir pith (FeFCCP) @ 6.25 t $ha^{-1}$) and 100% Zn + Fe Fortified Composted Coir pith (Zn+FeFCCP) @ 6.25 t $ha^{-1}$ as factor B were studied with brinjal. The results of the study clearly indicated that application of 125 % NPK along with Zn + Fe fortified composted coir pith (Zn+FeFCCP) was significantly superior in increasing the availability of major and micro nutrient status of coastal saline sandy soils and in increasing the nutritional quality along with yield of brinjal over other treatments.



**Key words:** Biofortification, Brinjal yield and quality, Coastal soil, Fortified organics, Micronutrients, Soil fertility


## INTRODUCTION

Human micronutrient deficiencies are a widespread problem worldwide and mainly concern people whose diet (mainly of plant origin) consists of insufficient amounts of critical vitamins and minerals. Low levels of micronutrients in plants are linked *i.e.*, their decreasing concentration in soils and/or low bioavailability and presence of abiotic stresses which disturb the proper growth and development of plants under coastal salt affected soils. Agronomic biofortification of crops is a very promising way to improve the concentration of micronutrients in edible parts of crops without compromising yield and is recognized as the cheapest strategy to alleviate hidden hunger worldwide. Nearly 2 billion peoples are globally suffers from micronutrient deficiencies, also known as a "hidden hunger" (Prom-u-thai*et al.* 2020). These deficiencies are usually prevalent in highly developed countries and are more common among growing and developing children, pregnant and lactating women, sportsmen, and manual labor workers. Among the micronutrients, those most associated with micronutrient malnutrition worldwide are zinc (Zn) and iron (Fe). Proper micro nutrition is key to good human health and according to the World Health Organization (WHO) of Human Organization (WHO), it mainly depends on sustainable agriculture (Athar *et al*., 2020). Unfortunately, current agricultural systems are still mostly oriented toward achieving high crop yields rather than nutritional quality, thus enhancing the concentrations of mineral micronutrients fortified with organic manures has become a key task in sustainable agriculture production. However, it is challenging to simultaneously increase the production of food enriched with essential micronutrients which does not cause obvious negative symptoms for plants like, *i.e.*, limiting growth and productivity as well as increased the nutrient content in the edible parts of plant and sustainable soil fertility in coastal saline soil.

Eggplant (*Solanum melongena* L.) or brinjal also known as "poor man's vegetable" is the fifth most important vegetable crop globally, grown on approximately 1.86 million hectares of land, with annual global production of around 54.1 million tonnes (FAO, 2021). India is the second largest producer of brinjal next to China, generating 61% and 23%, respectively, of the total annual yield. It is also having medicinal properties such as the potential to reduce cholesterol levels, rich in minerals, vitamins and essential amino acids and provide valuable nutrient supplement in the tropical diet. In India, coastal area extends up to 8,129 km coastline of the country. Tamil Nadu occupies 6,80,622 ha of coastal area constituting 26.8 per cent of the total area of the coastal districts. Coastal soils are generally deficient in organic matter and nutrients, poor physical properties and saline in nature. Brinjal is the heavy feeder of nutrients, deficiency of nutrient occurs due to continuous cultivation in coastal soil with imbalanced supply of nutrients to crop as they are poor in nutrient supplying capacity (Dimkpa and Bindraban, 2016). Additionally, crop cultivation in nutrient-deficient soils results in foods with low nutrient concentrations, particularly of micronutrients, which contributes to malnutrition and hidden hunger in many emerging-economy countries (Louhar*et al.*, 2020). Globally, micronutrient malnutrition arising either from inadequate consumption of fruits and vegetables or from consumption of foods which are low or deficient in essential micronutrients. Eating foods which have been biofortified to increase their micronutrient content is a useful pathway to overcome malnutrition for many. In order to reduce malnutrition, it is imperative to supply crops with micronutrients in addition to the macronutrients required for plant growth.

In sandy or sandy loam soils of coastal areas of Tamil Nadu, brinjal is the dominant vegetable crop. Low organic matter, poor nutrient status and loss of applied nutrients through leaching, there is a need to test the response of brinjal to increasing levels of NPK in these soils. Use of micronutrients (Zn and Fe) fortified organic manures to restore the soil fertility status has now been recognized. Additional inorganic nutrient along with fortified organic in coastal saline soil not only full fill the nutrients demand, but also helps in preventing loss of applied nutrients and steady release of them. Hence, use of micronutrients like zinc and iron fortified organic manures and inorganic sources of nutrient as best option for maintaining soil fertility and to achieve higher brinjal production was reported by many authors (Elayaraja, 2009 and Bana *et al.*, 2022). Keeping the above facts in mind, this study was conducted to evaluate the response of yield, quality and soil properties of brinjal through biofortification by zinc and iron fortified organic manure with NPK in coastal soil.

## MATERIALS AND METHODS

A field experiment was conducted in the farmer's field at Ponnanthittu coastal village, near Chidambaram, Cuddalore district, Tamil Nadu during August – December 2022. The experimental site is geographically located at 11°24′N latitude, 79°44′E longitudes and altitude of 5.79 M above mean sea level (MSL).The climate is moderately warm with a hot humid summer. The experimental soil was sandy in texture and taxonomically classified as *TypicUsticpsamments*. The physico- chemical characteristics of experimental soil was saline with pH of 8.54 and EC of 1.58 dS $m^{-1}$. It was low in organic carbon (2.31 g $kg^{-1}$), nitrogen (135.56 kg $ha^{-1}$), phosphorus (9.45 kg $ha^{-1}$), zinc (0.69 mg $kg^{-1}$), iron (3.87 mg $kg^{-1}$) and medium in potassium (157.30 kg $ha^{-1}$). The experiment consists of four levels of NPK (0, 100, 125, 150%)

and three combination of Zn & Fe fortified organics (100% Zn Fortified Composted Coir pith (ZnFCCP), 100% Fe Fortified Composted Coir pith (FeFCCP) and 100% Zn & Fe Fortified Composted Coir pith (Zn+FeFCCP) @ 6.25 t $ha^{-1}$ respectively) thus total of twelve treatment combinations was laid in randomized Block design (factorial). 35 day old seedling of Annamalai brinjal was used as test crop. Total Fruit yield was recorded at each harvest. Quality parameters and soil properties were estimated by the following methods *viz.*, Ascorbic acid content (Jackson, 1973),Total soluble solids, titrable acidity (Jackson, 1973), Bulk density and particle density (Measuring cylinder method, Tan, 1996), pH (Potentiometric method, Jackson, 1973), EC (Conductometric method, Jackson, 1973), organic carbon (Chromic acid wet digestion, Walkley and Black, 1934), available nitrogen (Alkaline potassium permanganate method by Subbiah and Asija, 1956), available phosphorus (0.5 M $NaHCO_3$, Watanabe and Olsen, 1954), available potassium (Neutral, normal ammonium acetate, Stanford and English, 1949), DTPA Zn and Fe (Atomic absorption spectrophotometer, Lindsay and Norwell, 1978). The data obtained were statistically analyzed as suggested by Gomez and Gomez (1984). For significant results, the critical difference was worked at five per cent probability level.

## RESULTS AND DISCUSSION

### Soil physical properties (Table 1)

All the micronutrients fortified organics applied treatment proved efficient in influencing the soil physical properties *viz.*, bulk density, particle density and water holding capacity of the soil in the present investigation. While, the different levels of NPK and interaction effect between NPK levels along with fortified organics were not significant.

The application of different level of NPK does not exhibit any significant influence on soil physical properties. Though all the fortified organics, application of Zn+ FeFCCP @ 6.25 t $ha^{-1}$ ($B_3$)performed well and registered the lowest bulk density (1.28Mg $m^{-3}$), particle density(2.69 Mg $m^{-3}$) and higher water holding capacity (29.87%) in soil. Addition of organic matter through organics provides organic binding agents which increase the aggregation, increase aeration and improve water holding capacity and decrease the water holding capacity. Saravaiya *et al.* (2010) also reported that addition of organics improve the physical condition of soil. Addition of organic matter possess more negative charge which holds large number of cations and there increase in physical properties of soil. This is lining with earlier findings of Thingujam *et al.* (2016).

**Soil physico-chemical properties (Table 2)**
**Soil reaction (pH)**

The effect of NPK levels in influencing the pH of the soil was not significant. The effect of different sources of micronutrients fortified organics application proved its worthiness in reducing the soil pH at post harvest stage. Among different micronutrients fortified organics evaluated, application of 100% recommended zinc and iron fortified composted coir pith (Zn+Fe FCCP) @ 6.25 t $ha^{-1}$ significantly reduced the pH in post harvest soil. At harvest, this treatment recorded the lowest pH of 7.90. The other micronutrients fortified organics namely 100% ZnFCCP and 100% FeFCCP also significantly reduced the pH of the soil to the tune of 7.96 and 8.02 at harvest as compared to a pH of 8.04 in NPK applied treatments (without fortified organics).

The interaction effect of different levels of NPK fertilizer along with different micronutrients fortified organics was not significant. Application of various micronutrients fortified organics brought out a significant reduction in pH and EC of the soil. All the micronutrients fortified organics evaluated contributed for a favourable improvement in the soil physico-chemical properties of soil by way of reduction in soil reaction and salinity. However, among the organics, application of Zn and Fe fortified composted coir pith excelled all others in reducing the pH and EC of the soil. The decrease in soil pH may be attributed to the higher production of $CO_2$ and organic acids on the decomposition of applied organic wastes which favourably reduced the pH of soil. This was in agreement accordance with the earlier findings of Vigneshvarraj (2020) and Rachanya (2022).

**Electrical conductivity (EC)**

All the micronutrients (Zn and Fe) fortified CCP application proved efficient in reducing the EC of soil at post harvest stages of brinjal. While, the interaction effect of NPK levels with micronutrients fortified composted coir pith were statistically not significant.

Though all the micronutrients fortified organic sources significantly reduced EC of soil, the lowest EC was recorded with treatment $B_3$, the application of 100% Zn+ Fe fortified composted coir pith (Zn+Fe FCCP) @ 12.5 t $ha^{-1}$ which recorded a EC value of 3.66 $dSm^{-1}$ at harvest stage. This was followed by treatment $B_1$, 100% zinc fortified composted coir pith (Zn FCCP) @ 6.25 t $ha^{-1}$and B2, 100% iron fortified composted coir pith (FeFCCP) @ 6.25 t $ha^{-1}$which recorded an EC value of 3.71and 3.79 $dSm^{-1}$ at post harvest soil, respectively. The highest EC was recorded in control (without fortified organics applied treatments).The increased permeability of soil and leaching of salts with the applied micronutrients fortified organics might have reduced the EC of soil. These results are in agreement with the earlier report of Vigneshvarraj (2020). Further, the better reduction in pH and EC with organics might be due to release of more organic acids during decomposition and also due to irrigation to crops during their growth period, it is quite probable that appreciable amount of salts might have been leached down apart from the formation of organometal complexes as observed by Thingujam *et al.* (2016).

**Soil organic carbon (SOC)**

The coastal sandy soil shows poor organic carbon status. Application of various sources of micronutrients like Zn and Fe fortified composted coir pith significantly increased the organic carbon content of soil, while, inorganic NPK levels and their interaction effect were not significant.

Of the various micronutrients fortified composted coir pith studied, application of 100% Zn + Fe fortified composted coirpith @ 6.25 t $ha^{-1}$ ($B_3$) recorded the maximum organic carbon content of 2.87 g $kg^{-1}$at harvest stage. This was followed by the treatment $B_1$, application of 100% ZnFCCP @ 6.25 t $ha^{-1}$and treatment $B_2$, application of 100% FeFCCP @ 6.25 t $ha^{-1}$which registered 2.79 and 2.70 g $kg^{-1}$, respectively at post harvest stage. The control registered the lowest organic carbon content 2.67 g $kg^{-1}$at post-harvest soil. The organic carbon status of the soil is an essential factor for soil productivity was significantly increased with the application of various micronutrients fortified organics sources. With the application of various micronutrients fortified organics, the content of organic carbon in the soil. The effects of application of inorganic NPK fertilizers were not significant in influencing the status of organic carbon. The addition of fortified organics directly and also the improved crop yields, resulted in increased left over of root and plant biomass in the soil which have increased the organic carbon status. These results are in line with findings of Mohankumar and Gowda (2010).

**Available major nutrients (Table 3)**

In the present study, the application of different levels of NPK along with various combination of fortified organic fertilizer favorably influence in increasing the availability of nutrients in soil and it was slightly reduced at harvest stage due to the crop intake of nutrients.

Among the various NPK levels, the application of NPK @ 150% ($A_4$) recorded the highest amount of alkaline $KMnO_4$-N (158.15 kg $ha^{-1}$), Olsen-P (11.91 kg $ha^{-1}$) and $NH_4OAC$-K (172.87 kg $ha^{-1}$). However, it was found to be comparable with the treatment $A_3$, the application of NPK @ 125 % (156.73 kg $ha^{-1}$ of available nitrogen, 11.85 kg $ha^{-1}$ of available phosphorus and 171.12 kg $ha^{-1}$ of available potassium). The lowest was observed with control ($A_1$).Among the various combination of FCCP tried the highest available N (147.55 kg $ha^{-1}$), P (11.42 kg $ha^{-1}$) and K (161.19 kg $ha^{-1}$) at harvest stages was recorded with the application of Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($B_3$). This was followed by the application of Zn FCCP @ 6.25 t $ha^{-1}$ ($B_1$) and lowest was recorded with Fe FCCP @ 6.25 t $ha^{-1}$ ($B_2$).

Regarding the interaction effect due to different levels of NPK and FCCP on major nutrient availability was significant. The highest alkaline $KMnO_4$-N content of 165.26 kg $ha^{-1}$, Olsen-P content of 12.21 kg $ha^{-1}$ and $NH_4OAC$-K content of 181.65 kg $ha^{-1}$ were recorded which received 150% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($A_4B_3$). This was equally efficacious with the application of 125% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($A_3B_3$). The lowest available nutrient content was noticed in control. The availability of nutrients in coastal saline soils are very low due to poor crop residues and microbial activity and leaching of nutrients associated with poor structure and low use efficiency of applied nutrients. The enhancement in soil nutrient levels was observed after crop harvest due to the balanced essential nutrient supplies in plant-available forms with organics, which also led to high rhizospheric biomass production, increasing soil organic matter and microbial activity, and ultimately improving soil fertility status. Similar findings reported by Suge *et al.* (2011).

**Available micronutrients (Fig.1)**

From the perusal of data, it is clear that the available Zn and Fe content of soil were significantly influenced by application of Zn through FCCP along with different levels of NPK fertilizers. Application of increasing levels of NPK from 0 to 150% increased the DTPA Zn and Fe in post-harvest soil. Among the graded levels of NPK applied, addition of NPK @ 150% ($A_4$) recorded the highest mean DTPA-Zn content of 1.19 mg $kg^{-1}$ and Fe content of 34.08mg $kg^{-1}$.

However, this was on par with the application of NPK @ 125% ($A_3$). The least available Zn and Fecontent was recorded in control. Among the various combination of FCCP tried, addition of Zn+Fe FCCP @ 6.25 t ha$^{-1}$ ($B_3$) excelled over the other treatments. This was followed by the treatments Zn FCCP @ 6.25 t ha$^{-1}$ ($B_1$) and Fe FCCP @6.25 t ha$^{-1}$ ($B_2$).

The Interaction between levels of NPK and FCCP on the available Zn and Fe content of soil was found to be significant. Application of 150% NPK along with Zn+Fe FCCP @ 6.25 t ha$^{-1}$ ($A_4B_3$) registered the highest available Zn content of 1.91, 1.64 and 1.25 mg kg$^{-1}$and Fe content of 87.86, 58.74 and 35.71 mg kg$^{-1}$at flowering, fruit formation and at harvest stage, respectively. This was equally efficient with the treatment which received 125% NPK along with Zn+FeFCCP @ 6.25 t ha$^{-1}$ ($A_3B_3$). This was followed by the treatment pairs $A_4B_1$ and $A_4B_2$. The lowest DTPA Zn and Fe content was observed in control treatment ($A_1B_2$).The increased Zn availability might be attributed to the direct addition of these nutrients by fortified organic manures, which maintain maximum available Zn and Fe status in post-harvest soil. Further the complexation of micronutrients with applied organics might have mobilized and increased the availability of Zn and Fe in soil. Elayaraja and Sathiyamurthi (2020) also reported.?

**Soil biological properties**
**Microbial populations (Table 5)**

Microbial populations of soil microorganisms *viz.*, bacteria, fungi and actinomycetes was also significantly increased with different combination of FCCP application along with different levels of NPK. Different levels of NPK show significant variation among the microbial populations in soil. The level which received NPK @ 150% ($A_4$) recorded highest count of bacteria (20.00 $\times 10^6$), fungi (12.67$\times 10^5$) and Actinomycetes (7.34 $\times 10^4$) in soil. This was on par with the application of NPK @ 125% ($A_3$) which registered a comparable bacterial count of 19.99 $\times 10^6$, fungi of 12.65$\times 10^5$ and actinomycetes of 7.33 $\times 10^4$. This was followed by the treatments $A_2$ and $A_1$. The various combination of FCCP application significantly increased the microbial populations in soil. Among the three treatments tried, application of Zn+Fe FCCP @ 6.25 t ha$^{-1}$ ($B_3$) performed well and registered the highest bacterial count of 19.73 $\times 10^6$, fungi of 12.47$\times 10^5$ and actinomycetes of 7.07 $\times 10^4$ in soil. The lowest microbial count was recorded with application of Fe FCCP @ 6.25 t ha$^{-1}$ ($B_2$).

The interaction effect between levels of NPK and FCCP on the microbial count in soil was found to be significant. Application of 150% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($A_4B_3$) recorded the highest microbial count of $20.11\times 10^6$, $12.78\times 10^5$ and $7.45\times 10^4$ by bacteria, fungi and actinomycetes, respectively. However, this was equally efficacious with the application of 125% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($A_3B_3$), while the lowest microbial count was recorded with control. Addition of organics creates a suitable environment for the survival of all microorganisms in soil. Decomposition of organics releases the acids and nutrients which regulate the soil pH and supply nutrients for the optimum growth of the microbes. Further, addition of fortified organics with NPK provides additional nutrients for the better proliferation of microbes (Nakhro and Dkhar, 2010)

**Enzyme activities (Fig 2)**

The enzymatic activity of soil *viz.,* dehydrogenase, phosphatase and urease was significantly increased with different combination of FCCP application along with different levels of NPK. Among the NPK levels application of NPK @ 150% ($A_4$) recorded the highest mean urease activity (30.45µg $NH_4$-N/g soil/24 h), alkaline phosphatase activity (13.44 µg *p*-nitrophenol/g soil/h) and dehydrogenase activity (72.61µg TTF/g soil/24 h) in the soil and this was comparable with the treatment $A_3$, the application of NPK @ 125%. The lowest enzymatic activities were observed in control. Among the various combination of FCCP tried, the application of Zn+Fe FCCP@6.25 t $ha^{-1}$ ($B_3$) recorded the highest urease activity of 29.96µg $NH_4$-N/g soil/24 h, alkaline phosphatase activity of 13.04 µg *p*-nitrophenol/g soil/hand dehydrogenase activity of 72.05µg TTF/g soil/24 h in the soil. This was followed by the application of Zn FCCP @ 6.25 t $ha^{-1}$ ($B_1$) and lowest with treatment supplied with Fe FCCP @ 6.25 t $ha^{-1}$ ($B_2$).

The interaction effect between levels of NPK and FCCP on the enzyme activity in soil was observed to be significant. Application of 150% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($A_4B_3$) registered the highest enzymatic activity of 30.45µg $NH_4$-N/g soil/24 h, 13.56 µg *p*-nitrophenol/g soil/h and 72.61µg TTF/g soil/24 h by bacteria, fungi and actinomycetes, respectively. This was equally efficient with the treatment ($A_3B_3$) which received 125% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$. The lowest enzymatic activity was recorded in the control treatment. Addition of fertilizer and organics increased the enzymatic activity in soil. Urease is important enzyme required for hydrolysis of urea, to release the ammonium ion required for the plant growth. Addition of nitrogen fertilizers and organics supply nitrogenase substance and also increased microbial activity which leads to increased urease activity in soil. Soil phosphatase activity is increased is mainly due to addition of phosphorus fertilizer and also regulation of soil pH through soil organics. Dehydrogenase enzyme is mainly involved in biological oxidation of organic matter in the soil by hydrogen transfer from the organic substrate to inorganic acceptors. Increase in dehydrogenase indicates the increase in biological activity and increase in nutrient availability in soil. Addition of organics resulted in increase in organic matter with increase in dehydrogenase activity. This is similar with findings of Ramamoorthy *et al.* (2018).

**Yield , quality and nutritional quality of brinjal Yield (Table 4)**

Application of different levels of NPK and different combinations of Zn and Fe fortified organic manure significantly enhanced the yield of brinjal. Among the different levels of NPK, application of NPK @ 150% ($A_4$) recorded the highest fruit yield and stover yield of brinjal. However, it was found to be equally efficacious with application of NPK @ 125%. Sandy soils are generally low in nutrient content than critical concentration which affects the plant growth and yield. Addition of extra NPK than normal recommended dose provides an optimum nutrient for the growth and ultimately increases the yield of crop. This is similar with findings of Aminifard *et al.* (2010) and Kasi *et al.* (2018). As the initially fertility is low and no nutrients are provided during the entire growth, plant might have exhausted of native nutrients from the soil which leads to the lowest yield in control as compared to the other treatments.

Among the three different combinations of fortified organics tried, application of 100% Zn & Fe FCCP @ 6.25 t $ha^{-1}$ ($B_3$) was significantly superior to other combination in increasing fruit yield and stover yield. This was followed by the application of Zn FCCP @ 6.25 t $ha^{-1}$ ($B_1$) and FeFCCP@ 6.25 t $ha^{-1}$($B_2$). Fortification of organic manure with the micronutrients improves the nutritional composition than normal content. Addition of fortified manures supplies the nutrient at steady rate throughout the growth of crop by decomposition, and improves physical condition of soil which increased the yield of crop. This is accordance with findings of Ramamoorthy *et al.*(2018).

The interaction effect between NPK levels and fortification of both Zn and Fe or either Zn or Fe alone through CCP on yield of brinjal was significant. The treatment $A_4B_3$, which received 150% NPK along with 100% Zn & Fe FCCP @ 6.25 t $ha^{-1}$ recorded the higher fruit yield and stover yield of brinjal as compared to other treatment combinations. However, it was found to be on par with 125% NPK along with Zn + Fe FCCP @ 6.25 t $ha^{-1}$ ($A_3B_3$). The lowest yield of brinjal was registered in sole fortified treatment ($A_1B_2$).The superiority of combined application of NPK with fortified organics may be due to increased nutrient uptake, as it provides optimum amount nutrient at steady rate which increases the plant growth The increased plant growth led to better carbohydrate build up with which increased the plant fruit yield. Suge *et al.* (2011) reported that addition of organic manure with inorganic fertilizer in the soil improves the soil physical and chemical properties which encourage better root development, increased nutrient uptake and water holding capacity which leads higher fruit yield.

**Quality parameters (Table 6)**

The quality parameters of brinjal *viz.,* ascorbic acid content, crude protein content, titrable acidity and total soluble solid was statistically enhanced by application of different levels of NPK and Zn + Fe FCCP.

Among the different levels of NPK evaluated, application of 150% NPK ($A_4$) recorded the highest mean ascorbic acid content, crude protein content, titrable acidity and total soluble solid in the brinjal. It recorded 15.79 mg 100 $g^{-1}$ fruit, 3.76, 1.73 and 14.86% respectively and this was comparable with the treatment $A_3$, the application of 125% NPK recorded a ascorbic acid content, crude protein content, titrable acidity and total soluble solid of 15.62 mg 100 $g^{-1}$ fruit, 3.71, 1.70 and 14.63%, respectively at the above said critical stages of brinjal. This was followed by the treatments $A_2$ and $A_1$ (control).Among the various combination of fortified organic fertilizer tried, application of Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($B_3$) recorded the highest ascorbic acid content, crude protein content, titrable acidity and total soluble solid of 14.66 mg 100 $g^{-1}$ fruit, 3.35, 1.50 and 13.74%, respectively. However, this was followed by the application of sole fortified organics through zinc and iron ($B_2$) and ($B_1$).

The interaction effect between different levels of NPK and FCCP on the quality parameters of brinjal was significant. Application of 150% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$ ($A_4B_3$) registered the highest ascorbic acid content, crude protein content, titrable acidity and total soluble solid of 16.59 mg 100 $g^{-1}$ fruit, 3.95%, 1.85% and 15.63%,respectively. This was equally efficient with treatment ($A_3B_3$) which received 125% NPK along with Zn+Fe FCCP @ 6.25 t $ha^{-1}$

and recorded the ascorbic acid content, crude protein content, titrable acidity and total soluble solid of 16.49 mg 100 g$^{-1}$fruit, 3.92%, %, 1.84% and 15.45% of brinjal, respectively. This was followed by the treatments $A_4B_1$ and $A_4B_2$. The lowest quality parameter of brinjal was recorded in Fe alone fortified treatment.

The quality parameters of brinjal obtained in presentation was due to the organic manures, during decomposition release nutrients, which became available to the plants and increased NPK concentration. The higher nutrients uptake with organic manure might be attributed to solubilisation of native nutrients through applied NPK fertilizers, chelation of micronutrient complex intermediate organic manures, their mobilization and accumulation of nutrients by crop plants. These results are in parity with results reported by Salwa *et al.* (2010); Grzebisz *et al.* (2010) and Chesti *et al.* (2015).

**Nutritional quality (Table 7)**

The quality parameters of brinjal *viz.*, zinc and iron content was statistically enhanced by application of different levels of NPK and Zn + Fe FCCP. Among the different levels of NPK evaluated, application of 150 % NPK ($A_4$) recorded the highest mean calcium (9.49mg 100g$^{-1}$fruit), phosphorus (0.69%), zinc (22.30%) and iron (5.22%) content and this was comparable with the treatment $A_3$. Among the various combination of fortified organic fertilizer tried, application of 100% Zn&Fe FCCP @ 6.25 t ha$^{-1}$ ($B_3$) recorded the highest calcium, phosphorus, zinc content and iron content of 8.83mg 100 g$^{-1}$fruit, 0.62%, 20.81% and 4.80%, respectively. However, this was followed by the application of sole fortified organics through zinc and iron ($B_2$ and $B_1$).

The interaction effect between different levels of NPK and FCCP on the quality parameters of brinjal was significant. Application of 150% NPK along with Zn + Fe FCCP @ 6.25 t ha$^{-1}$ ($A_4B_3$) registered the highest calcium, phosphorus, zinc content and iron content of 9.92mg 100 g$^{-1}$fruit, 0.73, 23.25 and 5.51%, respectively. This was equally efficient with treatment ($A_3B_3$) which received 125% NPK along with Zn +Fe FCCP @ 6.25 t ha$^{-1}$. The lowest nutritional quality parameter of brinjal was recorded in Fe alone fortified treatment. Supplementation of micronutrient with organics and additional macronutrient to crop supplies the entire essential nutrient for regulating all catalytic and enzymatic activities which improves the quality of fruit.  This was accordance with the results of Bana *et al.*(2021) who reported that nutrient supplementation with micronutrient-embedded fertilizer increases nutrient content in Eggplant Fruit.

## Conclusion

From the results of the present investigation, it is concluded that application of increasing level of NPK fertilizer along with Zn and Fe fortified compost has improved the soil properties, yield and quality of brinjal. From the various combination tried, combined application of 150% NPK fertilizer and 100% zinc and iron fortified coir pith compost resulted better than other treatment combination. So, this treatment combination may be recommended to the coastal brinjal growers for getting better profit and come over the micronutrient malnutrition through vegetables.

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**Table 1. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the physical properties of coastal saline soil**

| A / B | Bulk density (Mg m$^{-3}$) | | | | | Particle density (Mg m$^{-3}$) | | | | | Water holding capacity (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean |
| **$B_1$** | 1.32 | 1.32 | 1.33 | 1.34 | **1.33** | 2.83 | 2.80 | 2.76 | 2.74 | **2.78** | 29.50 | 29.59 | 29.61 | 29.66 | **29.59** |
| **$B_2$** | 1.31 | 1.32 | 1.32 | 1.31 | **1.31** | 2.92 | 2.91 | 2.87 | 2.84 | **2.89** | 29.20 | 29.30 | 29.31 | 29.35 | **29.29** |
| **$B_3$** | 1.30 | 1.29 | 1.26 | 1.27 | **1.28** | 2.72 | 2.70 | 2.67 | 2.65 | **2.69** | 29.78 | 29.85 | 29.92 | 29.94 | **29.87** |
| **Mean** | **1.32** | **1.31** | **1.30** | **1.30** | | **2.82** | **2.80** | **2.77** | **2.74** | | **29.49** | **29.58** | **29.61** | **29.65** | |
| | $SE_D$ | | | CD (p=0.05) | | $SE_D$ | | | CD (p=0.05) | | $SE_D$ | | | CD (p=0.05) | |
| **A** | NS | | | NS | | NS | | | NS | | NS | | | NS | |
| **B** | 0.01 | | | 0.02 | | 0.02 | | | 0.05 | | 0.06 | | | 0.13 | |
| **A x B** | NS | | | NS | | NS | | | NS | | NS | | | NS | |

**Table 2. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the physio-chemical properties of coastal saline soil**

| A / B | pH | | | | | EC (dSm$^{-1}$) | | | | | Organic carbon (g kg$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean |
| **$B_1$** | 7.99 | 7.96 | 7.97 | 7.95 | **7.96** | 3.73 | 3.71 | 3.71 | 3.70 | **3.71** | 2.76 | 2.78 | 2.80 | 2.81 | **2.79** |
| **$B_2$** | 8.01 | 8.03 | 8.04 | 8.03 | **8.02** | 3.80 | 3.78 | 3.79 | 3.77 | **3.79** | 2.67 | 2.70 | 2.70 | 2.72 | **2.70** |
| **$B_3$** | 7.98 | 7.90 | 7.89 | 7.88 | **7.90** | 3.67 | 3.66 | 3.65 | 3.64 | **3.66** | 2.84 | 2.85 | 2.88 | 2.89 | **2.87** |
| **Mean** | **8.04** | **7.96** | **7.97** | **7.95** | | **3.73** | **3.72** | **3.72** | **3.70** | | **2.76** | **2.78** | **2.79** | **2.81** | |
| | $SE_D$ | | | | CD (p=0.05) | $SE_D$ | | | | CD (p=0.05) | $SE_D$ | | | | CD (p=0.05) |
| **A** | NS | | | | NS | NS | | | | NS | NS | | | | NS |
| **B** | 0.01 | | | | 0.03 | 0.01 | | | | 0.03 | 0.02 | | | | 0.03 |
| **A x B** | NS | | | | NS | NS | | | | NS | NS | | | | NS |

**Table 3. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the available major nutrients in coastal saline soil**

| A / B | Available nitrogen (kg ha$^{-1}$) | | | | | Available phosphorus (kg ha$^{-1}$) | | | | | Available potassium (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean |
| **$B_1$** | 112.15 | 134.44 | 157.09 | 158.24 | **140.48** | 9.84 | 10.87 | 11.86 | 11.92 | **11.12** | 120.54 | 145.83 | 170.48 | 172.63 | **152.37** |
| **$B_2$** | 104.96 | 127.15 | 149.62 | 150.95 | **133.17** | 9.53 | 10.48 | 11.56 | 11.60 | **10.79** | 112.35 | 137.54 | 163.01 | 164.34 | **144.31** |
| **$B_3$** | 119.16 | 142.29 | 163.47 | 165.26 | **147.55** | 10.13 | 11.20 | 12.14 | 12.21 | **11.42** | 128.55 | 154.68 | 179.86 | 181.65 | **161.19** |
| **Mean** | **112.09** | **134.63** | **156.73** | **158.15** | | **9.83** | **10.85** | **11.85** | **11.91** | | **120.48** | **146.02** | **171.12** | **172.87** | |
| | | $SE_D$ | | CD (p=0.05) | | | $SE_D$ | | CD (p=0.05) | | | $SE_D$ | | CD (p=0.05) | |
| **A** | | 1.64 | | 3.39 | | | 0.06 | | 0.13 | | | 1.93 | | 3.99 | |
| **B** | | 1.88 | | 3.90 | | | 0.07 | | 0.15 | | | 2.21 | | 4.58 | |
| **A x B** | | 3.26 | | 6.74 | | | 0.13 | | 0.26 | | | 3.83 | | 7.93 | |

Factor – A (NPK Levels); $A_1$– control; $A_2$ – 100% NPK; $A_3$ – 125% NPK and $A_4$ – 150% NPK
Factor – B (Fortified CCP); $B_1$– 100% Zn fortified composted coir pith (ZnFCCP) @ 6.25 t ha$^{-1}$; $B_2$ – 100 % FeFCCP @ 6.25 t ha$^{-1}$and $B_3$ –100% Zn + Fe FCCP @ 6.25 t ha$^{-1}$

**Table 4. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the yield (t ha$^{-1}$) of brinjal**

| A / B | Fruit yield | | | | | Stover yield | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean |
| **$B_1$** | 40.57 | 45.04 | 49.91 | 50.56 | **46.52** | 33.69 | 37.88 | 41.81 | 42.02 | **38.85** |
| **$B_2$** | 39.09 | 43.55 | 48.28 | 48.87 | **44.95** | 32.21 | 36.59 | 40.41 | 40.69 | **37.48** |
| **$B_3$** | 42.04 | 46.73 | 51.64 | 52.11 | **48.13** | 35.08 | 39.07 | 42.91 | 43.27 | **40.08** |
| **Mean** | **40.57** | **45.11** | **49.94** | **50.51** | | **33.66** | **37.85** | **41.71** | **41.99** | |

| | Fruit yield $SE_D$ | Fruit yield CD (p=0.05) | Stover yield $SE_D$ | Stover yield CD (p=0.05) |
|---|---|---|---|---|
| **A** | 0.34 | 0.70 | 0.27 | 0.57 |
| **B** | 0.39 | 0.80 | 0.32 | 0.65 |
| **A x B** | 0.67 | 1.39 | 0.55 | 1.13 |

**Table 5. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the microbial population in coastal saline soil**

| A / B | Bacterial (x $10^6$/g soil) | | | | | Fungi(x $10^5$/g soil) | | | | | Actinomycetes(x $10^4$/g soil) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean | $A_1$ | $A_2$ | $A_3$ | $A_4$ | Mean |
| **$B_1$** | 18.78 | 19.61 | 19.99 | 20.01 | 19.60 | 11.88 | 12.27 | 12.66 | 12.69 | **12.38** | 6.64 | 6.95 | 7.33 | 7.35 | **7.07** |
| **$B_2$** | 18.59 | 19.52 | 19.87 | 19.89 | 19.47 | 11.76 | 12.19 | 12.52 | 12.55 | **12.26** | 6.51 | 6.86 | 7.21 | 7.23 | **6.95** |
| **$B_3$** | 18.97 | 19.73 | 20.1 | 20.11 | 19.73 | 11.97 | 12.38 | 12.76 | 12.78 | **12.47** | 6.75 | 7.07 | 7.44 | 7.45 | **7.18** |
| **Mean** | **18.78** | **19.62** | **19.99** | **20.00** | | **11.87** | **12.28** | **12.65** | **12.67** | | **6.63** | **6.96** | **7.33** | **7.34** | |

| | Bacterial $SE_D$ | Bacterial CD (p=0.05) | Fungi $SE_D$ | Fungi CD (p=0.05) | Actinomycetes $SE_D$ | Actinomycetes CD (p=0.05) |
|---|---|---|---|---|---|---|
| **A** | 0.01 | 0.03 | 0.02 | 0.04 | 0.02 | 0.04 |
| **B** | 0.02 | 0.03 | 0.02 | 0.04 | 0.02 | 0.05 |
| **A x B** | 0.03 | 0.06 | 0.03 | 0.07 | 0.04 | 0.08 |

Factor – A (NPK Levels); $A_1$– control; $A_2$ – 100% NPK; $A_3$ – 125% NPK and $A_4$ – 150% NPK
Factor – B (Fortified CCP); $B_1$– 100% Zn fortified composted coir pith (ZnFCCP) @ 6.25 t ha$^{-1}$; $B_2$ – 100 % FeFCCP @ 6.25 t ha$^{-1}$and $B_3$ –100% Zn + Fe FCCP @ 6.25 t ha$^{-1}$

**Table 6.Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the quality parameters of brinjal**

| A / B | Ascorbic acid content (mg 100 $g^{-1}$ fruit) | | | | | Crude protein content (%) | | | | | Titrable acidity (%) | | | | | Total soluble solid (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** |
| **$B_1$** | 10.66 | 13.25 | 15.65 | 15.82 | **13.85** | 2.09 | 2.88 | 3.71 | 3.77 | **3.11** | 0.84 | 1.24 | 1.70 | 1.74 | **1.38** | 10.06 | 12.32 | 14.67 | 14.88 | **12.98** |
| **$B_2$** | 9.78 | 12.56 | 14.73 | 14.97 | **13.01** | 1.87 | 2.63 | 3.51 | 3.55 | **2.89** | 0.67 | 1.12 | 1.56 | 1.59 | **1.24** | 9.37 | 11.57 | 13.78 | 14.06 | **12.20** |
| **$B_3$** | 11.59 | 13.96 | 16.49 | 16.59 | **14.66** | 2.34 | 3.17 | 3.92 | 3.95 | **3.35** | 0.94 | 1.37 | 1.84 | 1.85 | **1.50** | 10.87 | 13.01 | 15.45 | 15.63 | **13.74** |
| **Mean** | **10.68** | **13.26** | **15.62** | **15.79** | | **2.10** | **2.89** | **3.71** | **3.76** | | **0.82** | **1.24** | **1.70** | **1.73** | | **10.10** | **12.30** | **14.63** | **14.86** | |

| | $SE_D$ | CD (p=0.05) | $SE_D$ | CD (p=0.05) | $SE_D$ | CD (p=0.05) | $SE_D$ | CD (p=0.05) |
|---|---|---|---|---|---|---|---|---|
| **A** | 0.15 | 0.31 | 0.04 | 0.08 | 0.02 | 0.05 | 0.15 | 0.31 |
| **B** | 0.17 | 0.35 | 0.04 | 0.09 | 0.03 | 0.05 | 0.17 | 0.36 |
| **A x B** | 0.29 | 0.61 | 0.07 | 0.15 | 0.04 | 0.09 | 0.30 | 0.62 |

**Table 7.Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the nutritional quality parameters of brinjal**

| A / B | Calcium (mg 100 $g^{-1}$fruit) | | | | | Phosphorus (%) | | | | | Zinc content (%) | | | | | Iron content (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** | **Mean** |
| **$B_1$** | 6.54 | 7.90 | 9.40 | 9.51 | **8.34** | 0.38 | 0.54 | 0.67 | 0.69 | **0.57** | 15.89 | 18.86 | 21.95 | 22.26 | **19.74** | 3.35 | 4.27 | 5.14 | 5.22 | **4.50** |
| **$B_2$** | 6.01 | 7.48 | 8.95 | 9.03 | **7.87** | 0.33 | 0.48 | 0.63 | 0.64 | **0.52** | 14.84 | 17.79 | 21.12 | 21.38 | **18.78** | 2.99 | 3.93 | 4.86 | 4.92 | **4.18** |
| **$B_3$** | 7.03 | 8.49 | 9.88 | 9.92 | **8.83** | 0.44 | 0.58 | 0.72 | 0.73 | **0.62** | 16.81 | 20.11 | 23.08 | 23.25 | **20.81** | 3.68 | 4.55 | 5.47 | 5.51 | **4.80** |
| **Mean** | **6.53** | **7.96** | **9.41** | **9.49** | | **0.38** | **0.53** | **0.67** | **0.69** | | **15.85** | **18.92** | **22.05** | **22.30** | | **3.34** | **4.25** | **5.16** | **5.22** | |

| | $SE_D$ | CD (p=0.05) | $SE_D$ | CD (p=0.05) | $SE_D$ | CD (p=0.05) | $SE_D$ | CD (p=0.05) |
|---|---|---|---|---|---|---|---|---|
| **A** | 0.09 | 0.19 | 0.01 | 0.02 | 0.21 | 0.43 | 0.05 | 0.11 |
| **B** | 0.11 | 0.22 | 0.01 | 0.02 | 0.24 | 0.49 | 0.06 | 0.12 |
| **A x B** | 0.18 | 0.38 | 0.01 | 0.03 | 0.41 | 0.85 | 0.10 | 0.21 |

Factor – A (NPK Levels); $A_1$– control; $A_2$ – 100% NPK; $A_3$ – 125% NPK and $A_4$ – 150% NPK
Factor – B (Fortified CCP); $B_1$– 100% Zn fortified composted coir pith (ZnFCCP) @ 6.25 t $ha^{-1}$; $B_2$ – 100 % FeFCCP @ 6.25 t $ha^{-1}$and $B_3$ –100% Zn + Fe FCCP @ 6.25 t $ha^{-1}$

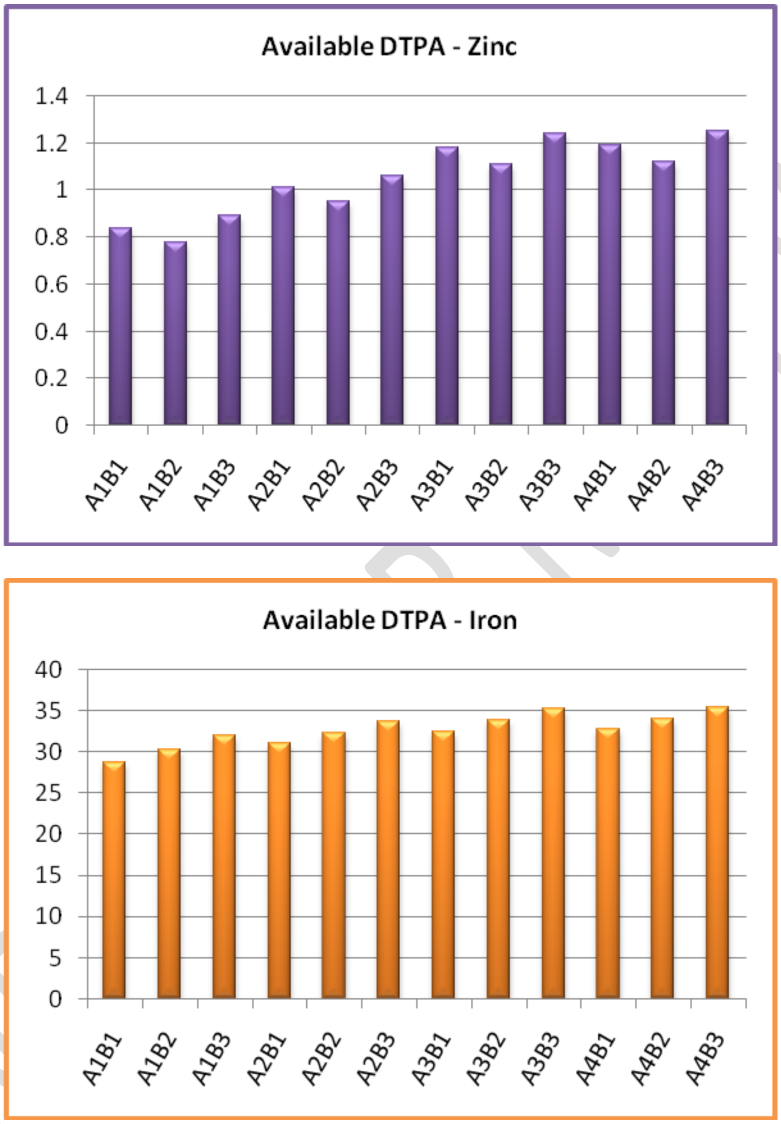
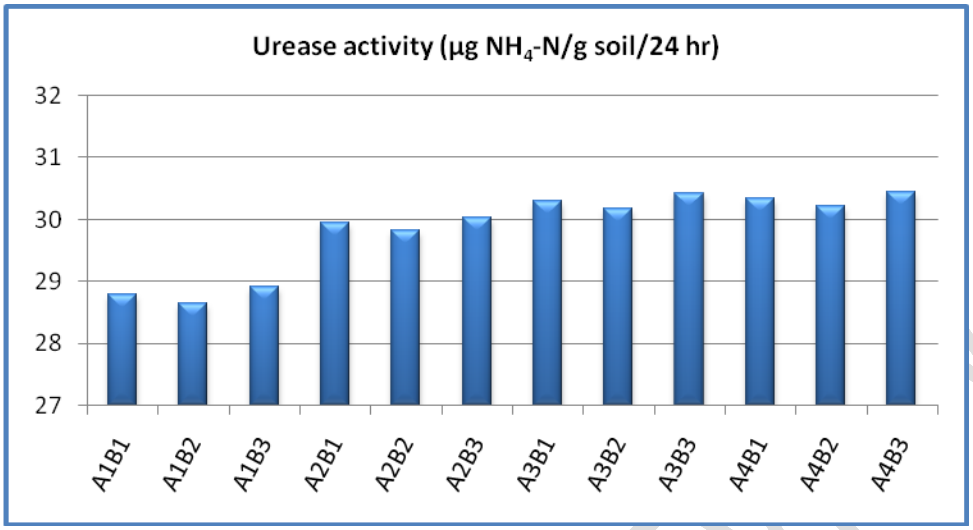
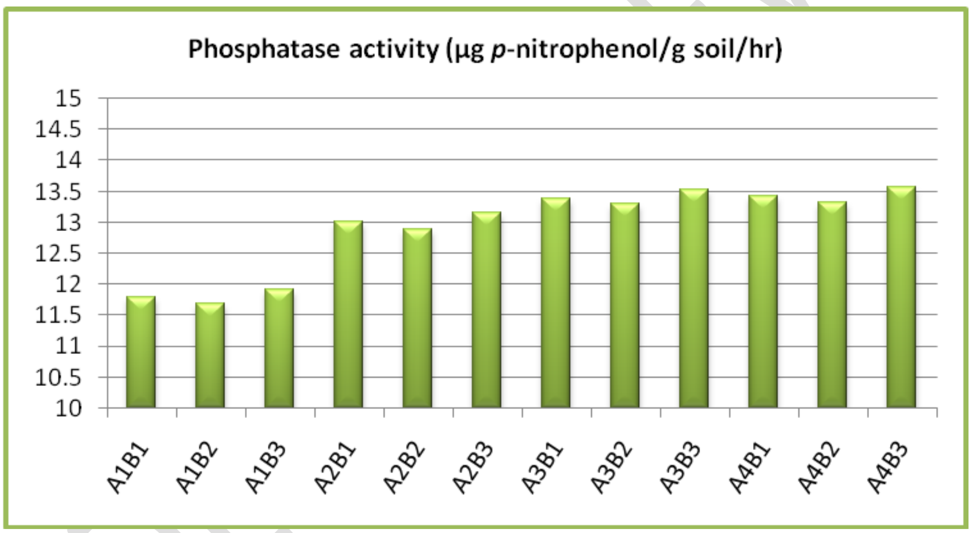



**Fig. 1. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the available micronutrients (mg $kg^{-1}$) in coastal saline soil**


Urease activity (µg NH4-N/g soil/24 hr)
32
31
30
29
28
27
A1B1
A1B2
A1B3
A2B1
A2B2
A2B3
A3B1
A3B2
A3B3
A4B1
A4B2
A4B3


Phosphatase activity (µg p-nitrophenol/g soil/hr)
15
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
A1B1
A1B2
A1B3
A2B1
A2B2
A2B3
A3B1
A3B2
A3B3
A4B1
A4B2
A4B3

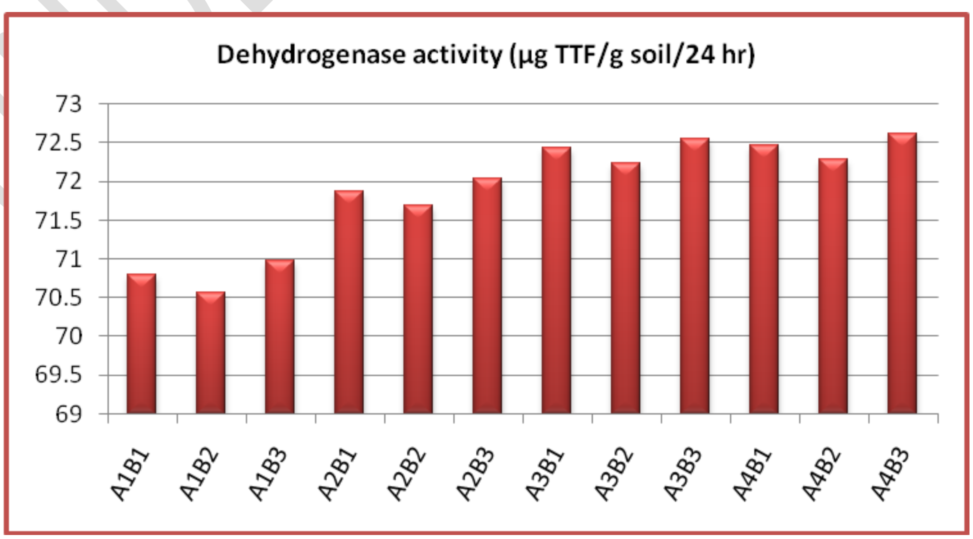

Dehydrogenase activity (µg TTF/g soil/24 hr)
73
72.5
72
71.5
71
70.5
70
69.5
69
A1B1
A1B2
A1B3
A2B1
A2B2
A2B3
A3B1
A3B2
A3B3
A4B1
A4B2
A4B3

**Fig. 2. Effect of biofortification of Zn and Fe through fortified organics along with NPK levels on the enzyme activities in post-harvest soil**