Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

**E-ISSN:** 2278-4136
**P-ISSN:** 2349-8234
JPP 2019; 8(1): 2447-2451
Received: 16-11-2018
Accepted: 18-12-2018

**GM Prashantha**
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

**SS Prakash**
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

**S Umesha**
Department of Agricultural Microbiology, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

**T Chikkaramappa**
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

**CT Subbarayappa**
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

**V Ramamurthy**
Principal Scientist, NBSS&LUP, Hebbal, Bangalore, Karnataka, India

**Correspondence**
**GM Prashantha**
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India

# Direct and residual effect of zinc and boron on soil enzyme activities at harvest in finger millet-groundnut cropping system

**GM Prashantha, SS Prakash, S Umesha, T Chikkaramappa, CT Subbarayappa and V Ramamurthy**

## Abstract
Field experiments were conducted during 2015-16 and 2016-17 in the farmer's field at Gutthikatte Village, Hosadurga taluk, Chitradurga district to study the direct and residual effect of zinc and boron on soil enzyme activity. The experiments were laid out in a randomized complete block design with fifteen treatments replicated thrice. The treatments were composed of recommended NPK with varied levels of Zn and B with FYM. The pooled analysis revealed that the direct application of RDF + FYM + $ZnSO_4$ @ 15 kg $ha^{-1}$ + Borax @ 12.5 kg $ha^{-1}$ and residual effect of RDF + FYM + $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 12.5 kg $ha^{-1}$ recorded significantly higher dehydrogenase and urease activities were observed in post-harvest soils of both finger millet and groundnut crops compare to other treatments.

**Keywords:** Groundnut, boron, residual effect, soil enzyme, zinc.

## Introduction
Finger millet (*Eleusine coracana* (L.) Gaertn.) is a major food crop of the semi-arid tropics of Asia and Africa. In India, it is grown on an area of 1.19 m ha with a production of 1.98 m t with an average productivity of 1661 kg $ha^{-1}$. The major finger millet growing states are Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Jharkhand,
Maharashtra and Uttaranchal. Karnataka is the largest producer of finger millet grown on an area of 1.05 m ha with a production of 1.57 m t and the average productivity is 1889 kg $ha^{-1}$ (Anonymous, 2015) [3].

Groundnut (*Arachis hypogaea* L.) is a major edible oil seed and a food crop of the world. It is popularly called as poor man's almond and considered as king of oilseeds. Groundnut occupies an area of 24.7 m ha with a production of 33 m t in the world. In India groundnut occupies an area of 7.40 m ha with a production of 4.59 m t and productivity of 1764 kg $ha^{-1}$. Karnataka ranks fifth in the country with a production of 0.50 m t from an area of 0.65 m ha with productivity of 844 kg $ha^{-1}$ (Anonymous, 2016) [4]. Even though it is an energy rich crop, the cultivation of groundnut mainly confined to marginal and less fertile soils in India with inadequate nutrition. Groundnut is a potential oilseed crop of semi-arid region which is generally grown after finger millet in many of the southern districts of Karnataka. It can be successfully raised on residual fertility where the previous finger millet crop received adequate nutrition including deficient micronutrients.

Micronutrient deficiencies in crop plants are widespread because of increased use of high analysis macronutrient fertilizers, growing of high yielding crop cultivars and decreased use of organic manures. Singh and Behera (2011) [13] reported that as much as 48, 12, 5, 4, 33, 13 and 41 per cent soils in India are affected with deficiency of Zn, Fe, Mn, Cu, B, Mo and S, respectively. Among micronutrients, zinc is one of the essential micronutrient elements and is required by crop plants in very small amounts. It plays a significant role in various enzymatic and physiological activities and performs many catalytic functions in plant system besides transformation of carbohydrates, chlorophyll and protein synthesis. Next to Zn, boron is important in cell division and helps in germination and growth of pollen grains, sugar translocation and movement of growth regulators within the plant and lignin synthesis.

Soil enzymes play the key biochemical functions in the overall process of organic matter decomposition in soil system (Mandal *et al*., 2013) [9]. These enzymes are constantly being synthesized, accumulated, inactivated and/or decomposed in the soil hence playing very important role in crop production particularly in nutrients cycling (Tabatabai, 1994) [14]. The enzyme levels in soil systems may vary in amounts primarily due to the soil type and cropping effects that need to be investigated for every region.

A better understanding of these soil enzymes would provide the basis in maintaining soil health and potentially provide a unique opportunity to manage soil fertility. Therefore, the present studies were conducted to direct and residual effect of zinc and boron on soil enzyme activities viz dehydrogenase and urease at harvest in finger millet – groundnut cropping system.

## Material and Methods

The field experiments were conducted under irrigated condition in the farmer's field at Gutthikatte village, Hosadurga taluk, Chitradurga district during *kharif* and summer seasons of 2015-16 to 2016-17. The initial physical, chemical and biological properties of soil were estimated by using appropriate methods given in Table 1. The experiments were laid out in randomized complete block design with fifteen treatments and replicated thrice. The two experiments were conducted during *kharif* 2015 and 2016 with finger millet (GPU-28) main crop and the residual effect of the said treatments were studied during summer seasons of 2016 and 2017 with Groundnut (ICGV-91114) as succeeding crop.

The treatments comprise of $T_1$: Absolute control, $T_2$: RDF (only NPK), $T_3$: RDF + FYM, $T_4$: Only FYM, $T_5$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$, $T_6$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$, $T_7$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$, $T_8$: $T_3$+ Borax @ 10 kg $ha^{-1}$, $T_9$: $T_3$+ Borax @ 12.5 kg $ha^{-1}$, $T_{10}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$, $T_{11}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$, $T_{12}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$, $T_{13}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$, $T_{14}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ and $T_{15}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$. The recommended NPK fertilizers (100:50:50 kg $ha^{-1}$) and FYM (10 t $ha^{-1}$) were applied to finger millet main crop as per the UAS, package. Groundnut cultivated as a succeeding crop.

### Assay of enzyme activity in soil

Soil samples of each treatmental plot were collected at harvest stage, and were immediately stored in polythene bags. The soils were preserved and stored at 5°C in a refrigerator until analysis. These samples were utilized for the assay of soil enzyme activity.

#### Methods employed for determination of enzyme activity in soil

### Dehydrogenase activity

Determination of dehydrogenase activity was carried out by adopting the methodology given by Casida *et al.* (1964) [5]. It is based on the principle that 2, 3, 5-triphenyl tetrazolium chloride (TTC), used as electron acceptor in place of $O_2$, is reduced to triphenyl formazan (TPF). The quantity of TPF formed which is directly proportional to the dehydrogenase activity. The activity is expressed as µg of TPF formed $g^{-1}$ soil $h^{-1}$ at 37 ± 2 $^0$C.

### Urease activity

Determination of urease activity was carried out by adopting the methodology as given by Eivazi and Tabatabai (1977). In this method, the unhydrolyzed urea was complexed with a coloring agent and the color intensity is directly proportional to the urea present. The quantity of urea hydrolyzed is computed based on the initial and final urea present and expressed as µg urea hydrolyzed $g^{-1}$ $h^{-1}$ at 37 ± 2 $^0$C.

**Table 1** Initial physical, chemical and biological properties of soil in the study area

| S. No. | Particulars | Value obtained |
|---|---|---|
| **I** | **Physical properties of soil** | |
| **1** | **Mechanical properties of soil (% oven dry basis)** | |
| | Sand (%) | 51.42 |
| | Silt (%) | 21.51 |
| | Clay (%) | 27.07 |
| | Textural class | Sandy clay loam |
| 2 | Maximum water holding capacity (%) | 43.52 |
| 3 | Bulk density (Mg $m^{-3}$) | 1.44 |
| **II** | **Chemical properties of soil** | |
| 1 | pH (1:2.5) | 7.23 |
| 2 | Electrical conductivity (d $Sm^{-1}$) | 0.45 |
| 3 | Organic carbon (%) | 0.53 |
| 4 | Cation exchange capacity [c mol ($p^+$) $kg^{-1}$] | 11.32 |
| 5 | Available N (kg $ha^{-1}$) | 288.6 |
| 6 | Available $P_2O_5$ (kg $ha^{-1}$) | 23.22 |
| 7 | Available $K_2O$ (kg $ha^{-1}$) | 152.2 |
| 8 | Exch.Ca [c mol ($p^+$) $kg^{-1}$] | 4.14 |
| 9 | Exch. Mg [c mol ($p^+$) $kg^{-1}$] | 1.68 |
| 10 | Available S (mg $kg^{-1}$) | 8.15 |
| 11 | DTPA Fe (mg $kg^{-1}$) | 2.76 |
| 12 | DTPA Mn (mg $kg^{-1}$) | 2.58 |
| 13 | DTPA Zn (mg $kg^{-1}$) | 0.48 |
| 14 | DTPA Cu (mg $kg^{-1}$) | 0.89 |
| 15 | Hot water soluble B (mg $kg^{-1}$) | 0.36 |
| **III** | **Biological properties of soil** | |
| 1 | Dehydrogenase activity (µg TPF $g^{-1}$ soil $24hr^{-1}$) | 58.85 |
| 2 | Urease activity (µg $NH_4^+$- N $g^{-1}$ $2hr^{-1}$) | 16.86 |

## Results and Discussion

The soil enzyme activities of crops differed significantly during first (2015-16) and second (2016-17) year of experiments and the pattern of response to zinc and boron application was similar in both the years. Therefore, only pooled data of the two years are used to highlight the results and discussed in this chapter.

**Effect of graded levels of zinc and boron on enzyme activities at harvest of finger millet**

**Dehydrogenase and Urease activities**

Significantly higher dehydrogenase and urease activities were observed in RDF + FYM + $ZnSO_4$ @ 15 kg $ha^{-1}$ + Borax @ 12.5 kg $ha^{-1}$ (104.93 µg TPF $g^{-1}$ soil $day^{-1}$ and 33.64 µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$)but was on par with RDF + FYM + $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 12.5 kg $ha^{-1}$ (102.69 µg TPF $g^{-1}$ soil $day^{-1}$ and 32.30 µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$, respectively). Lowest dehydrogenase and urease activities were observed with absolute control (45.40 µg TPF $g^{-1}$ soil $day^{-1}$ and 13.29 µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$,respectively) (Table 2 and Figure 1). The treatments receiving soil application of zinc have lead to increased activity of enzymes. Addition of trace metals like zinc to soil might influence microbial proliferation and enzyme activity possibly leading to an increase in rates of biochemical process in the soil environment. However, when application of abnormally higher concentration rate they could cause in inhibition of enzyme activity. It has been observed that trace elements act as activator of enzymes in soil which varies with the soil, the concentration and the form of added trace elements on the enzyme assay.

Dehydrogenase is an enzyme, which acts as an index to soil microbial activity. The dehydrogenase activity in the present study was significantly higher due to application of NPK + FYM + $ZnSO_4$ + Borax as compared to control (Table 2 and Figure 1). Moreover, the FYM treated plots were found to be extremely superior in the removal of hydrogen. FYM is the source of carbon and carbon is the source of energy for microbes which multiply very fast by utilizing carbon leading to increased population. It might be probably due to the increased population of soil microbes by the addition of FYM which inturn released this enzyme. These results are in conformity with those of Manna *et al*. (2005) [10] and Anonymous (2007) [2]. The urease activity as observed in this study indicates that, significant differences were observed due to application of micronutrients along with recommended NPK and FYM in both the cropping systems, combined application of FYM with NPK and micronutrients ($T_{13}$) produced significantly higher activity of urease as in the case of other enzymes. The role of farm yard manure is multidimensional ranging from building up of organic matter, maintaining favourable soil physical properties and balanced supply of nutrients which promoted the activity of soil microbes which helped in recording higher activity of urease. FYM contains 20 to 23% carbon. This carbon is the source of energy for soil microbes. They utilize this energy and multiply. Due to increased population of microbes enzyme activities in soil also increase. Indeed, the present results are in confirmation with those of Manna *et al*. (2005) [10] and Anonymous (2007) [2]. Rama Lakshmi *et al.* (2014) [12] also observed increase in urease activity in manured treatments due to higher microbial activity as compared to control treatments.

**Residual effect of graded levels of zinc and boron on enzymatic activities of soil at harvest in succeeding crop of groundnut**

**Dehydrogenase and urease activities**

A significantly higher dehydrogenase and urease activities were observed in $T_{15}$ of 124.17 µg TPF $g^{-1}$ soil $day^{-1}$ and 36.53 µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$ which received RDF + FYM + $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 12.5 kg $ha^{-1}$ and it was on par with $T_{14}$ (RDF + FYM + $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 10 kg $ha^{-1}$) of 142.63 µg TPF $g^{-1}$ soil $day^{-1}$ and 35.22 µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$, respectively. Lowest dehydrogenase and urease activities were observed in $T_1$ (absolute control) of 38.37 µg TPF $g^{-1}$ soil $day^{-1}$ and 12.03 µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$, respectively (Table 3 & Figure 2). Dehydrogenase is an enzyme, which acts as an index to soil microbial activity. The dehydrogenase activity in the present study was significantly higher due to application of RDF + FYM + $ZnSO_4$ @ 20 kg $ha^{-1}$ +

**Table 2:** Effect of graded levels of zinc and boron on dehydrogenase and urease activities of soil after harvest of finger millet in finger millet – groundnut cropping system

| Treatments | Dehydrogenase activity (µg TPF $g^{-1}$ $24h^{-1}$) | | | Urease activity (µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | Pooled mean | 2015-16 | 2016-17 | Pooled mean |
| 1 | 53.28 | 37.51 | 45.40 | 14.50 | 12.08 | 13.29 |
| 2 | 61.00 | 70.75 | 65.88 | 16.43 | 21.68 | 19.06 |
| 3 | 66.48 | 73.85 | 70.17 | 17.68 | 23.43 | 20.56 |
| 4 | 56.67 | 68.84 | 62.76 | 15.31 | 19.27 | 17.29 |
| 5 | 71.58 | 89.48 | 80.53 | 20.02 | 25.82 | 22.92 |
| 6 | 77.00 | 96.25 | 86.63 | 23.60 | 28.86 | 26.23 |
| 7 | 73.37 | 91.71 | 82.54 | 22.08 | 26.29 | 24.19 |
| 8 | 66.53 | 75.66 | 71.10 | 16.74 | 23.73 | 20.24 |
| 9 | 68.41 | 85.51 | 76.96 | 20.08 | 24.16 | 22.12 |
| 10 | 77.67 | 97.09 | 87.38 | 24.00 | 29.02 | 26.51 |
| 11 | 84.00 | 105.00 | 94.50 | 26.72 | 30.68 | 28.70 |
| 12 | 84.10 | 105.13 | 94.62 | 26.78 | 31.72 | 29.25 |
| 13 | 93.27 | 116.59 | 104.93 | 30.68 | 36.59 | 33.64 |
| 14 | 84.57 | 105.71 | 95.14 | 26.93 | 32.85 | 29.89 |
| 15 | 91.28 | 114.10 | 102.69 | 29.86 | 34.74 | 32.30 |
| S.Em± | 1.33 | 1.62 | 1.48 | 0.40 | 0.47 | 0.44 |
| CD @5% | 3.89 | 4.74 | 4.31 | 1.17 | 1.39 | 1.28 |

| | | |
|---|---|---|
| $T_1$: Absolute control | $T_6$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$ | $T_{11}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$ |
| $T_2$:RDF (only NPK) | $T_7$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$ | $T_{12}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ |
| $T_3$:RDF + FYM | $T_8$: $T_3$+ Borax @ 10 kg $ha^{-1}$ | $T_{13}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$ |
| $T_4$:Only FYM | $T_9$: $T_3$+ Borax @ 12.5 kg $ha^{-1}$ | $T_{14}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ |
| $T_5$:$T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$ | $T_{10}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ | $T_{15}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$ |

**Table 3:** Residual effect of graded levels of zinc and boron on dehydrogenase and urease activities of soil after harvest of groundnut in finger millet – groundnut cropping system

| Treatments | Dehydrogenase activity (µg TPF $g^{-1}$ $24h^{-1}$) | | | Urease activity (µg $NH_4^+$ - N $g^{-1}$ soil $2h^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | Pooled mean | 2015-16 | 2016-17 | Pooled mean |
| 1 | 42.63 | 34.10 | 38.37 | 12.74 | 11.31 | 12.03 |
| 2 | 66.10 | 79.69 | 72.90 | 19.51 | 23.75 | 21.63 |
| 3 | 68.23 | 89.81 | 79.02 | 20.40 | 24.52 | 22.46 |
| 4 | 64.74 | 63.55 | 64.15 | 18.90 | 20.29 | 19.60 |
| 5 | 78.74 | 111.84 | 95.29 | 22.69 | 30.56 | 26.63 |
| 6 | 84.70 | 120.31 | 102.51 | 25.11 | 32.25 | 28.68 |
| 7 | 80.71 | 114.64 | 97.68 | 24.49 | 31.09 | 27.79 |
| 8 | 73.58 | 94.58 | 84.08 | 20.76 | 25.12 | 22.94 |
| 9 | 75.25 | 106.89 | 91.07 | 21.28 | 29.08 | 25.18 |
| 10 | 85.44 | 121.36 | 103.40 | 25.41 | 33.00 | 29.21 |
| 11 | 92.40 | 131.25 | 111.83 | 27.24 | 35.15 | 31.20 |
| 12 | 92.51 | 131.41 | 111.96 | 28.28 | 35.70 | 31.99 |
| 13 | 93.03 | 132.14 | 112.59 | 29.42 | 37.52 | 33.47 |
| 14 | 100.41 | 142.63 | 121.52 | 31.48 | 38.95 | 35.22 |
| 15 | 102.60 | 145.73 | 124.17 | 32.37 | 40.68 | 36.53 |
| S.Em± | 1.45 | 1.96 | 1.70 | 0.43 | 0.54 | 0.49 |
| CD @5% | 4.25 | 5.72 | 4.97 | 1.27 | 1.58 | 1.42 |

| | | |
|---|---|---|
| $T_1$: Absolute control | $T_6$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$ | $T_{11}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$ |
| $T_2$:RDF (only NPK) | $T_7$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$ | $T_{12}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ |
| $T_3$:RDF + FYM | $T_8$: $T_3$+ Borax @ 10 kg $ha^{-1}$ | $T_{13}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$ |
| $T_4$:Only FYM | $T_9$: $T_3$+ Borax @ 12.5 kg $ha^{-1}$ | $T_{14}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ |
| $T_5$:$T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$ | $T_{10}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$ | $T_{15}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$ |

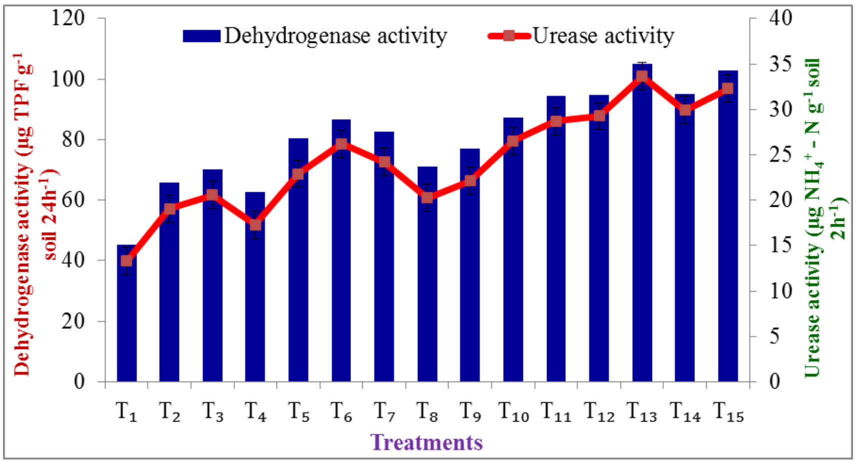


**Fig 1:** Effect of graded levels of zinc and boron on enzyme activities of soil after harvest of finger millet in finger millet – groundnut cropping system

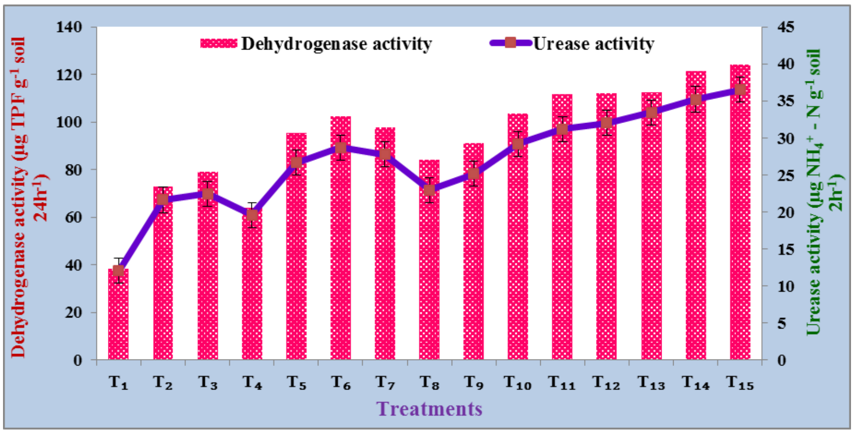


**Fig 2:** Residual effect of graded levels of zinc and boron on enzyme activities of soil after harvest of groundnut in finger millet – groundnut cropping system Legend

$T_1$: Absolute control
$T_2$: RDF (only NPK)
$T_3$: RDF + FYM
$T_4$: Only FYM
$T_5$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$
$T_6$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$
$T_7$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$
$T_8$: $T_3$+ Borax @ 10 kg $ha^{-1}$
$T_9$: $T_3$+ Borax @ 12.5 kg $ha^{-1}$
$T_{10}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$
$T_{11}$: $T_3$+ $ZnSO_4$ @ 12.5 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$
$T_{12}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$
$T_{13}$: $T_3$+ $ZnSO_4$ @ 15 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$
$T_{14}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 10 kg $ha^{-1}$
$T_{15}$: $T_3$+ $ZnSO_4$ @ 20 kg $ha^{-1}$+ Borax @ 12.5 kg $ha^{-1}$

Borax @ 12.5 kg ha$^{-1}$ ($T_{15}$) as compared to control. Moreover, the FYM treated plots were found to be extremely superior in the removal of hydrogen. It might be probably due to the increased population of soil microbes by the addition of FYM which in turn released this enzyme. These results are in conformity with those of Anonymous (2007) [2] and Ramalakshmi (2011).

Higher dehydrogenase activity was observed in higher dose of fertilizer applied treatments along with organic manures, this might be due to increased microbial activity as a result of increased availability of substrate (organic carbon) supplied through FYM applied plots. Application of balanced nutrients at higher levels in combination with organics and inorganics improved the organic status of soil which in turn enhanced dehydrogenase activity (Masto *et al*., 2006) [11].

Higher dehydrogenase activity was observed in higher dose of fertilizer applied treatments along with organic manures, this might be due to increased microbial activity as a result of increased availability of substrate (organic carbon) supplied through FYM applied plots. Application of balanced nutrients at higher levels in combination with organics and inorganics improved the organic status of soil which in turn enhanced dehydrogenase activity (Masto *et al*., 2006) [11].

## Conclusion

It can be concluded that direct application of RDF + FYM + $ZnSO_4$ @ 15 kg ha$^{-1}$ + Borax @ 12.5 kg ha$^{-1}$ and residual effect of RDF + FYM + $ZnSO_4$ @ 20 kg ha$^{-1}$ + Borax @ 12.5 kg ha$^{-1}$ recorded significantly higher dehydrogenase and urease activities were observed in post-harvest soils of both finger millet and groundnut crops compare to other treatments.

## References


1. Amanda Shylla, Microbial and biochemical soil health indicators for dry land agriculture in Alfisols. M.Sc. (Agri.) Thesis (Unpub.), Univ. Agric. Sci., Bengaluru, 2012.
2. Anonymous, Micronutrient management for enhancing the productivity of finger millet- pulse-oil seed based productivity system for Alfisols of Karnataka. Annual Report of Micronutrient Project 2006-07, All India Co-ordinated Research Project for Dry land Agriculture, UAS, Bangalore, 2007, 39-52.
3. Anonymous, Area, production and productivity of millets. Directorate of Economics and Statistics, 2015.
4. Anonymous, Agriculture statistics at a glance. Government of India, New Delhi, 2016, 78-81.
5. Casida LEJR, Klein DA, Santaro T. Soil dehydrogenase activity. Soil Sci. 1964; 96:371-376.
6. Chakrabarti K, Sarkar B, Chakraborty A, Banik P, Bagchi DK. Organic recycling for soil quality conservation in a sub-tropical plateau region. J. Agron. Crop Sci. 2000; 184:137-142.
7. Dilly O, Munch JCH, Pfeiffer EM. Enzyme activities and litter decomposition in agricultural soils in northern, central, and southern Germany. J Pl. Nutr. Soil Sci., 2007; 170:197-204.
8. Eivazi F, Tabatabi MA. Phosphates in soils. Soil Biol. Biochem. 1977; 9:167-172.
9. Mandal KG, Majhi P, Sahoo DK. Rout R. Kumar A. Ghosh S *et al.* Assessing the soil environment under major cropping systems in Kuanria canal command. Ecol. Environ. Cons., 2013; 19(2):509-513.
10. Manna MC, Swarup A, Wanjari RH, Ravikar HN, Mishra B, Saha MN, Long term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub humid and semi-arid tropical India. Field Crop Res. 2005; 93:264-280.
11. Masto RE, Chhonkar PK, Singh D, Patra AK. Changes in soil biological and biochemical characteristics in a long-term field trial on a subtropical Inceptisol. Soil Biol. Biochem. 2006; 38(7):1577-1582.
12. Rama Lakshmi Ch S, Rao PC, Sreelatha T, Madhavi M, Padmaja G, Rao PV. Cumulative and Residual Effects of INM of *Kharif* Rice on Soil Enzyme Activities in Rabi Green gram (*Vigna Radiata)*. Legume res., Inter. J., 2014; 4: 408-414.
13. Singh MV, Behera SK. AICRP on micro and secondary nutrients and pollutants elements in soils and plants. A Profile, Res. Bull. 2011; 10:1-57.
14. Tabatabai MA, Soil enzymes. In: Methods of soil analysis: microbiological and biochemical properties (RW Weaver, JS Angle and PS Bottomley eds), Part 2, SSSA Book Series # 5, Soil Sci. Soc. America, Madison, WI, 1994.