**Influence of integrated nitrogen management on release pattern of Zn, Fe, Mn and Cu under different soil moisture regimes**

**Abstract:**

**A** laboratory incubation experiment was conducted for two consecutive years during 2015-16 and 2016-17 to ascertain the effect of integrated nitrogen management on release pattern of nutrients overtime at different moisture regimes in soils at COA, CAU, and Imphal-04.The experiment consisted of 12 treatments with three different soil moisture regimes. For incubation study, the soil samples were periodically collected and analyzed at 30 days intervals after incubation of Zn, Fe, Mn and Cu. Incubation study was conducted by discard method. The experiment was led out in FRBD.

Analysis of the data of incubation study revealed that irrespective of different treatments accumulation of available, Fe and Mn gradually increased up-to 60th day of incubation, thereafter continued to decrease slowly up to the last stage of incubation. Comparatively, greater accumulation DTPA-extractable Zn, Cu was also observed at 60 % WHC followed by 40 % and 80 % WHC at different stages of incubation .Among the treatments, significantly higher concentration of available Zn and Mn was observed in T11 followed by T6. Further, the data pointed out that statistically higher accumulation of DTPA extractable Cu in soil was perceived in T4 followed by T11 throughout the incubation period.

**Keywords:** integrated nitrogen management, moisture regime, DTPA – extractant, vermicompost,

**Introduction**

Application of organic wastes as a source of organic matter is a common practice to improve soil properties (Baran, 2001).Distribution of trace element between soil and solution is the key to evaluate the environmental impact of the metals. So, the efficient management of micronutrients (Zn, Fe, Mn and Cu) is vital to sustain the productivity of different crops and to maintain a healthy balance of nutrients in soils.

When organic materials added to the soil mineralization to release nutrients slowly and the rate of nutrient mineralize increases as the plant growth progresses. As the plant matures, it is expected that a good soil would have released adequate nutrients for optimum plant growth (Lekasi *et.al*.2005). Organic matter is an important secondary source of trace elements in soil. Most micronutrients are held tightly in complex organic compounds and may not be readily available to plants. However, they can be an important source of micronutrients when they are slowly released into a plant available form as organic matter decomposes (Choudhary *et al*.2008)

**Materials and Methods**

An acid soil having the physico-chemical properties as presented in Table 1 was collected from research field of College of Agriculture, CAU, Imphal, by taking several thin slices from the surface soil layer (0-20 cm) as outlined by Jackson (1973). Soil texture, pH, EC, Organic carbon, cation exchange capacity (CEC), available N,P,K and DTPA extractable - Zn, Fe, Mn, Cu were also determined following the standard procedure described by Jackson (1973); Lindsay and Norvell (1978).The composite soils were air dried in shade, ground and passed through 2mm sieve. The processed soils were stored in polyethylene bags and used for the experiment. Hundred gram of air dried soil was taken in each of a series of 100 mL beakers. Urea, Vermicompost and Azolla equivalent to recommended dose of nitrogen for rapeseed-mustard were mixed thoroughly with the soil according to different set of treatments. Azotobacter was applied @ 2 kg per acre. Soils of each treatment were moistened to three different moisture regimes viz. 40% (W1), 60% (W2) and 80% (W3) of water holding capacity (WHC) and kept at room temperature throughout the experiment. The loss of moisture was replenished by periodic addition of sterile distilled water on every alternate day by difference in weight. The beakers were kept covered with black polythene sheet and incubated for a period of 90 days. Separate sets of treatments were maintained for each of the sampling stages. Incubation study was conducted by discard method. The experiment was carried out under Factorial randomized block design (FRBD).

1. **Treatment Details:**

T0- Control

T1- 100 % RDN using chemical fertilizer Urea

T2- 100% using Vermicompost as N-source

T3- 100% using *Azolla* as N-source

T4- 75% RDN using (Urea) + 25% RDN using Vermicompost

T5- 75% RDN using (Urea) + 25% using *Azolla* + *Azotobacter*

T6- 50% RDN using (Urea) + 50% RDN using Vermicompost

T7- 50% RDN using (Urea) + 50% using *Azolla* + *Azotobacter*

T8- 25% RDN using (Urea) + 75% RDN using Vermicompost

T9- 25% RDN using (Urea) + 75% using *Azolla* + *Azotobacter*

T10- 100 % RDN using Vermicompost +100 %using *Azolla* + *Azotobacter*

T11- 100 % RDN using chemical fertilizer + 100 % RDN using Vermicompost + 100 % using *Azolla* + *Azotobacter*

1. **Moisture regimes:**

W1- 40% WHC (Water holding capacity)

W2- 60% WHC (Water holding capacity)

W3- 80% WHC (Water holding capacity)

Soil samples were periodically collected and analyzed on 0th, 30th, 60th and 90th days of incubation to determine the release pattern of nutrients under different moisture regimes in soil.

**Statistical analysis**

Data obtained from the experiments were statistically analyzed through analysis of variance technique for comparing the treatments effects as described by Gomez and Gomez (1984). The significance of various effects was tested at 5% level of probability.

**Result and Discussion**

**DTPA-extractable zinc (Zn)**

Data shown in table 2 represent the effect of INM and moisture regimes on DTPA-extractable zinc content in soil. In general, irrespective of different treatments and moisture regimes, DTPA-extractable zincgradually decreased throughout the incubation period. The decrease in DTPA-extractable zinc in soil might be due to immobilization because of applied organic sources (Angelova *et al.,* 2013). Closer investigation of the data revealed that significantly greater accumulation of DTPA-extractable zinc was observed at 60% WHC followed by 40% and 80% WHC at different stages of incubation. It signified that DTPA-extractable zinc content in soil decreased with increasing moisture level. Application of organic matter combined with saturated moisture regime brought about decrease in zinc content suggesting immobilization and the antagonistic effect of increased concentration of extractable iron, manganese and phosphorus (Haldar and Mandal, 1979).

The data further revealed that application of either chemical fertilizers or organic manures or in conjunction of both the sources increased DTPA-extractable zinc in soil over untreated control. Similar results were also reported earlier by other investigators (Dhaliwal *et al*., 2012, Lakshmi *et al.*, 2013a; Baishya *et al.*, 2015; Zeid *et al.*, 2015 and Jat and Singh, 2017). Irrespective of moisture regimes, statistically higher accumulation of DTPA-extractable zinc was recorded in combined application of inorganic and organic N sources than inorganic fertilizers alone. Similar findings were also given by Swarup and Yaduvanshi (2000) and Balwinder *et al*. (2008). This implied that combined application of organic and inorganic N sources soil induced the release of nutrients from organic sources thereby increasing soil availability along with inorganic sources (Gautam *et al*., 2013). Abdul Salam and Subramanian (1988) also reported the interaction between Zn and N was synergistic. Comparing among the different treatments, significantly higher DTPA-extractable zinc in soil was recorded in T11 at different periods of incubation followed by T4 showing parity with T6 and T8 on 90th day of incubation. In case of 30th and 60th day, comparatively higher zinc was maintained in T11 followed by T5 and T8. There was a significant interaction between treatments and moisture on 90th day of incubation.

**DTPA-extractable iron (Fe)**

Data regarding the changes in the amount of soil DTPA-extractable iron as influenced by INM and moisture regimes are given in Table 3. Irrespective of different treatments and moisture regimes, an increase in the concentration of DTPA extractable Fe was observed with the addition of different N sources. The amount of DTPA extractable Fe increased rapidly to a maximum on 60th day of incubation, then gradually declined till the end of the experiment under different moisture regimes (40%, 60% and 80% WHC).The result was at parity with the work of Safarzadeh *et al*. (2018). The production of organic and inorganic acids during the degradation of organic fertilizers had a contribution in decreasing soil pH leading to increase in available amounts of elements in the rhizosphere zone (Lakshmi *et al.*, 2013b; Baishya *et al.*, 2015; Zeid *et al.*, 2015 and Patel and Tiwari, 2018). The decrease in DTPA extractable Fe indicated immobilization due to application of organic sources (Angelova *et al.,* 2013). Closer examination of the data revealed that significantly greater accumulation of DTPA-extractable Fe was observed at 80% WHC followed by 60% and 40% WHC at different stages of incubation. Irrespective of different moisture regimes, results pointed out that significantly higher accumulation of DTPA extractable Fe was noticed in the entire N treated soils than untreated control at different stages of incubation. The result showed similarity with earlier works of Patel and Tiwari (2018) and Safarzadeh *et al*. (2018). Further perusal of the data showed that integration of inorganic and organic N sources resulted significantly higher amount of DTPA extractable Fe than inorganic treated soil (T1). Enhancement in Fe content in integrated treatments might be due to gradual release of nutrients from organic sources which increased the nutrients to the soil along with inorganic source and made it available to the soil (Helgason *et al.,* 2007; Baitilwake *et al.,* 2012 and Gautam *et al*., 2013).

**Table 1:** Initial soil characteristics of the incubation experiment

|  |  |
| --- | --- |
| **Soil characteristics** | **Results** |
| Textural class | Clayey soil |
| Sand (%) | 8.24 |
| Silt (%) | 13.44 |
| Clay (%) | 78.32 |
| pH (1:2.5 soil : water ratio) | 5.40 |
| EC (1:2.5 soil : water ratio, dsm-1) | 0.28 |
| CEC [cmol(p+) kg-1] | 34.05 |
| Organic carbon (%) | 1.56 |
| Available Nitrogen (Kg N ha-1) | 389.39 |
| Available Phosphorus (Kg P2O5 ha-1) | 57.71 |
| Available potassium (Kg K2O ha-1) | 252.67 |
| DTPA extractable Zn (mg kg-1)) | 0.80 |
| DTPA extractable Fe (mg kg-1)) | 94.38 |
| DTPA extractable Mn (mg kg-1)) | 35.81 |
| DTPA extractable Cu (mg kg-1)) | 0.96 |

Among the different treatments, significantly greater accumulation of DTPA extractable Fe was found in T11 throughout the study followed by T4 which was at par with T8 on 30th day of incubation but T11 was at par with T4 on 60th and 90th days of incubation followed by T8 and T6.

**DTPA-extractable manganese (Mn)**

Perusal of the data Table 4 showed that similar trend of DTPA extractable Mn in soil was observed under different moisture regimes (40%, 60% and 80% WHC). The trend showed an increase rapidly to a maximum up to 60th day followed by a gradual decline till the end of the experiment excepting T0 and T1 presenting decreasing tend till the end of the experiment. The decline might be due to immobilization because of added organic sources (Angelova *et al.,* 2013). Analysis of the data showed that significantly higher DTPA extractable Mn content in soil was observed at higher moisture regime i.e. 80% WHC followed by 60% and 40% at different days of incubation. Irrespective of moisture regimes, an increase in the concentration of DTPA extractable Mn was observed with the addition of organic sources at different levels. Application of organics might have increased the water soluble plus exchangeable and easily reducible fractions of Mn. According to Das and Mandal (1986), organic matter addition enhanced the initial decrease in redox potential and increases water soluble and exchangeable Mn2+ in soil.

Further study of the data observed that single or combined application of different inorganic and organic N sources at different levels gave significantly greater amount of DTPA extractable Mn in soil as compared to untreated control. The results were supported by Swarup and Yaduvanshi (2000); Garai *et al*. (2014); Baishya *et al.* (2015) and Zeid *et al.* (2015). However, integration of inorganic and organic N sources resulted in significantly higher concentration of DTPA extractable Mn in soil than inorganically treated soil (T1) (Balwinder *et al*., 2008). Comparing among the different treatments, statistically higher DTPA extractable Mn accumulation was recorded in T11 followed by T10 which was statistically similar with T6 on 30th and 90th days of incubation. However, comparatively higher DTPA extractable Mn concentration was maintained in T11 which was statistically similar with T6 and T10 on 60th day of incubation. There was an interaction effect between treatments and moisture on 60th and 90th day of incubation.

**Table 2. Effect of INM and moisture regimes on DTPA extractable Zn (mg kg-1) in soil**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Incubation days | | | | | | | | | | | | | | | | | |
| 0 | | | | 30 | | | | 60 | | | | 90 | | | | | |
| W1 | W2 | W3 | Mean | W1 | W2 | W3 | Mean | W1 | W2 | W3 | Mean | W1 | W2 | | W3 | Mean | |
| T0 | 0.85 | 0.85 | 0.85 | 0.85 | 0.65 | 0.65 | 0.61 | 0.64 | 0.59 | 0.58 | 0.55 | 0.57 | 0.40 | | 0.41 | 0.38 | | 0.40 |
| T1 | 0.86 | 0.87 | 0.87 | 0.87 | 0.68 | 0.68 | 0.67 | 0.68 | 0.60 | 0.62 | 0.58 | 0.60 | 0.42 | | 0.46 | 0.43 | | 0.44 |
| T2 | 0.86 | 0.87 | 0.86 | 0.86 | 0.71 | 0.72 | 0.69 | 0.71 | 0.62 | 0.63 | 0.63 | 0.63 | 0.44 | | 0.43 | 0.43 | | 0.43 |
| T3 | 0.85 | 0.86 | 0.85 | 0.85 | 0.69 | 0.69 | 0.66 | 0.68 | 0.60 | 0.61 | 0.59 | 0.60 | 0.43 | | 0.44 | 0.42 | | 0.43 |
| T4 | 0.87 | 0.86 | 0.85 | 0.86 | 0.70 | 0.71 | 0.68 | 0.70 | 0.63 | 0.63 | 0.62 | 0.63 | 0.47 | | 0.50 | 0.46 | | 0.48 |
| T5 | 0.88 | 0.88 | 0.86 | 0.87 | 0.73 | 0.75 | 0.71 | 0.73 | 0.66 | 0.67 | 0.64 | 0.66 | 0.46 | | 0.48 | 0.45 | | 0.46 |
| T6 | 0.87 | 0.87 | 0.86 | 0.87 | 0.71 | 0.72 | 0.70 | 0.71 | 0.65 | 0.66 | 0.64 | 0.65 | 0.46 | | 0.49 | 0.46 | | 0.47 |
| T7 | 0.87 | 0.88 | 0.87 | 0.87 | 0.70 | 0.71 | 0.69 | 0.70 | 0.63 | 0.65 | 0.62 | 0.63 | 0.45 | | 0.47 | 0.44 | | 0.45 |
| T8 | 0.88 | 0.88 | 0.86 | 0.87 | 0.72 | 0.75 | 0.71 | 0.73 | 0.66 | 0.68 | 0.65 | 0.66 | 0.47 | | 0.49 | 0.45 | | 0.47 |
| T9 | 0.85 | 0.85 | 0.85 | 0.85 | 0.71 | 0.74 | 0.70 | 0.72 | 0.65 | 0.65 | 0.64 | 0.65 | 0.46 | | 0.48 | 0.45 | | 0.46 |
| T10 | 0.86 | 0.87 | 0.86 | 0.86 | 0.70 | 0.72 | 0.69 | 0.70 | 0.62 | 0.62 | 0.61 | 0.62 | 0.45 | | 0.44 | 0.45 | | 0.45 |
| T11 | 0.87 | 0.88 | 0.87 | 0.87 | 0.75 | 0.77 | 0.74 | 0.75 | 0.68 | 0.70 | 0.67 | 0.68 | 0.51 | | 0.54 | 0.50 | | 0.52 |
| Mean | 0.86 | 0.87 | 0.86 |  | 0.70 | 0.72 | 0.69 |  | 0.63 | 0.64 | 0.62 |  | 0.45 | | 0.47 | 0.44 | |  |
| Source | SE(d) ± | | CD0.05 | | SE(d) ± | | CD0.05 | | SE(d) ± | | CD0.05 | | SE(d) ± | | | CD0.05 | | |
| T  W  T X W | 0.004  0.001  0.011 | | 0.007  0.002  0.022 | | 0.003  0.001  0.010 | | 0.007  0.002  0.020 | | 0.002  0.001  0.007 | | 0.005  0.001  0.014 | | 0.002  0.000  0.006 | | | 0.004  0.001  0.012 | | |

**Table 3. Effect of INM and moisture regimes on DTPA extractable Fe (mg kg-1) in soil**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Incubation days | | | | | | | | | | | | | | | | | | | |
| 0 | | | | 30 | | | | | | 60 | | | | 90 | | | | | |
| W1 | W2 | W3 | Mean | W1 | | W2 | | W3 | Mean | W1 | W2 | W3 | Mean | W1 | W2 | | W3 | Mean | |
| T0 | 93.00 | 94.32 | 95.90 | 94.41 | | 94.35 | 95.98 | | 96.00 | 95.44 | 97.10 | 96.54 | 97.30 | 96.98 | 84.25 | | 84.50 | 84.86 | | 84.54 |
| T1 | 93.50 | 94.69 | 96.10 | 94.76 | | 95.56 | 96.00 | | 97.99 | 96.52 | 99.25 | 99.65 | 99.07 | 99.32 | 85.52 | | 86.10 | 86.54 | | 86.05 |
| T2 | 94.00 | 95.00 | 96.35 | 95.12 | | 106.10 | 108.25 | | 109.25 | 107.87 | 116.56 | 114.00 | 113.52 | 114.69 | 109.25 | | 107.52 | 106.68 | | 107.82 |
| T3 | 94.52 | 95.63 | 95.62 | 95.26 | | 105.50 | 108.35 | | 108.90 | 107.58 | 114.00 | 114.56 | 116.25 | 114.94 | 105.54 | | 105.98 | 107.65 | | 106.39 |
| T4 | 95.10 | 95.40 | 95.00 | 95.17 | | 110.20 | 111.20 | | 113.00 | 111.47 | 119.52 | 120.21 | 120.69 | 120.14 | 111.00 | | 112.56 | 112.95 | | 112.17 |
| T5 | 95.00 | 94.89 | 95.65 | 95.18 | | 105.52 | 107.00 | | 109.98 | 107.50 | 111.58 | 112.56 | 114.56 | 112.90 | 105.80 | | 106.35 | 108.23 | | 106.79 |
| T6 | 94.25 | 95.00 | 96.50 | 95.25 | | 109.89 | 109.20 | | 111.00 | 110.03 | 117.56 | 117.90 | 118.00 | 117.82 | 108.25 | | 110.25 | 110.00 | | 109.50 |
| T7 | 94.68 | 94.68 | 96.23 | 95.20 | | 107.50 | 108.25 | | 110.25 | 108.67 | 115.35 | 116.00 | 116.52 | 115.96 | 107.00 | | 108.00 | 108.96 | | 107.99 |
| T8 | 95.10 | 95.00 | 96.12 | 95.41 | | 110.00 | 110.85 | | 111.20 | 110.68 | 118.20 | 119.25 | 120.65 | 119.37 | 110.65 | | 111.52 | 110.65 | | 110.94 |
| T9 | 95.00 | 95.10 | 95.69 | 95.26 | | 108.52 | 110.00 | | 111.65 | 110.06 | 117.00 | 117.69 | 118.32 | 117.67 | 108.25 | | 110.20 | 109.56 | | 109.34 |
| T10 | 95.00 | 95.31 | 95.00 | 95.10 | | 106.00 | 110.32 | | 110.00 | 108.77 | 113.25 | 117.98 | 118.20 | 116.48 | 106.30 | | 109.89 | 111.20 | | 109.13 |
| T11 | 94.68 | 95.00 | 96.20 | 95.29 | | 112.45 | 112.69 | | 113.50 | 112.88 | 121.54 | 121.98 | 122.00 | 121.84 | 111.56 | | 112.00 | 113.50 | | 112.35 |
| Mean | 94.49 | 95.00 | 95.86 |  | | 105.97 | 107.34 | | 108.56 |  | 113.41 | 114.03 | 114.59 |  | 104.45 | | 105.41 | 105.90 | |  |
| Source | SE(d) ± | | CD0.05 | | | SE(d) ± | | CD0.05 | | | SE(d) ± | | CD0.05 | | SE(d) ± | | | CD0.05 | | |
| T | 1.15  0.29  3.46 | | 2.30  0.58  6.91 | | | 0.58  0.15  1.75 | | 1.16  0.29  3.49 | | | 0.91  0.23  2.72 | | 1.81  0.45  5.43 | | 0.35  0.09  1.05 | | | 0.70  0.17  2.10 | | |
| W |
| T X W |

**Table 4. Effect of INM and moisture regimes on DTPA extractable Mn (mg kg-1) in soil**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Incubation days | | | | | | | | | | | | | | | | | | | |
| 0 | | | | 30 | | | | | | 60 | | | | 90 | | | | | |
| W1 | W2 | W3 | Mean | W1 | | W2 | | W3 | Mean | W1 | W2 | W3 | Mean | W1 | W2 | | W3 | Mean | |
| T0 | 33.25 | 34.00 | 34.21 | 33.82 | | 31.25 | 31.00 | | 31.25 | 31.17 | 30.54 | 30.00 | 30.95 | 30.50 | 25.36 | | 26.10 | 28.52 | | 26.66 |
| T1 | 34.20 | 34.10 | 34.20 | 34.17 | | 34.12 | 34.10 | | 34.16 | 34.13 | 32.56 | 33.10 | 32.56 | 32.74 | 29.54 | | 30.00 | 30.20 | | 29.91 |
| T2 | 35.65 | 35.66 | 34.52 | 35.28 | | 50.52 | 52.35 | | 53.00 | 51.96 | 52.35 | 53.65 | 58.10 | 54.70 | 40.62 | | 41.25 | 47.21 | | 43.03 |
| T3 | 35.45 | 36.45 | 35.21 | 35.70 | | 48.24 | 50.10 | | 50.23 | 49.52 | 51.35 | 52.35 | 53.40 | 52.37 | 42.12 | | 43.00 | 44.18 | | 43.10 |
| T4 | 36.54 | 36.00 | 35.85 | 36.13 | | 49.63 | 49.69 | | 49.52 | 49.61 | 55.25 | 56.25 | 53.25 | 54.92 | 44.89 | | 45.52 | 44.25 | | 44.89 |
| T5 | 36.89 | 35.24 | 35.00 | 35.71 | | 48.65 | 48.85 | | 49.98 | 49.16 | 51.23 | 51.35 | 52.00 | 51.53 | 42.00 | | 42.65 | 43.25 | | 42.63 |
| T6 | 35.54 | 35.48 | 34.56 | 35.19 | | 50.95 | 51.00 | | 49.65 | 50.53 | 55.25 | 57.00 | 56.23 | 56.16 | 45.23 | | 45.00 | 46.00 | | 45.41 |
| T7 | 34.26 | 34.95 | 35.10 | 34.77 | | 48.66 | 50.23 | | 51.26 | 50.05 | 52.10 | 53.00 | 54.50 | 53.20 | 42.20 | | 43.00 | 43.65 | | 42.95 |
| T8 | 34.00 | 36.00 | 34.56 | 34.85 | | 51.20 | 51.98 | | 52.00 | 51.73 | 54.23 | 55.35 | 57.00 | 55.53 | 44.65 | | 43.56 | 46.30 | | 44.84 |
| T9 | 35.65 | 34.98 | 35.23 | 35.29 | | 50.00 | 50.23 | | 50.65 | 50.29 | 52.35 | 53.89 | 55.23 | 53.82 | 43.50 | | 44.32 | 44.56 | | 44.13 |
| T10 | 36.25 | 36.10 | 35.64 | 36.00 | | 52.30 | 52.38 | | 52.65 | 52.44 | 53.00 | 56.96 | 57.90 | 55.95 | 43.56 | | 46.00 | 48.24 | | 45.93 |
| T11 | 35.50 | 36.54 | 35.60 | 35.88 | | 53.40 | 53.78 | | 54.10 | 53.76 | 55.60 | 57.21 | 58.13 | 56.98 | 48.65 | | 48.90 | 50.10 | | 49.22 |
| Mean | 35.27 | 35.46 | 34.97 |  | | 47.41 | 47.97 | | 48.20 |  | 49.65 | 50.84 | 51.60 |  | 41.03 | | 41.61 | 43.04 | |  |
| Source | SE(d) ± | | CD0.05 | | | SE(d) ± | | CD0.05 | | | SE(d) ± | | CD0.05 | | SE(d) ± | | | CD0.05 | | |
| T | 0.15  0.04  0.44 | | 0.29  0.07  0.87 | | | 0.20  0.05  0.59 | | 0.39  0.10  1.18 | | | 0.21  0.05  0.63 | | 0.42  0.11  1.27 | | 0.18  0.05  0.55 | | | 0.36  0.09  1.09 | | |
| W |
| T X W |

**DTPA-extractable copper (Cu)**

Data on the effect of INM and moisture regimes on DTPA extractable Cu content in soil are presented in Table 5. Irrespective of different treatments and moisture regimes, there was a declining trend in soil DTPA extractable Cu with increase in the period of experiment under different moisture regimes (40%, 60% and 80% WHC). Similar finding was also observed by Chaudhary *et al*. (2011). The decrease in DTPA-extractable Cu in soil might be due to immobilization by humic substances from applied organic sources (Angelova *et al.,* 2013). Critical analysis of the data revealed that significantly higher amount of DTPA extractable Cu was accumulated in soil treated with 60% WHC followed by 40% WHC from 30th day onwards up to 60th day of incubation. However, at the end of the experiment, accumulation at 40% WHC was significantly greater than 60% WHC.

Further perusal of the data revealed that irrespective of different moisture levels and sampling days, significantly higher accumulation of DTPA extractable Cu in soil was found in different inorganic and organic N sources treated soil than untreated control. This is in corroboration with the results of Balwinder *et al*. (2008); Dhaliwal *et al*. (2012); Baishya *et al.* (2015); Zeid *et al.* (2015) and Jat and Singh (2017). Comparing the data between combined application of inorganic and organic N sources and sole application of inorganic fertilizer, it was observed that significantly higher amount of DTPA extractable Cu in soil was recorded in integration of inorganic and organic N sources than sole application. The presence of organic matter may increase the availability of Cu in soils owing to the formation of soluble complexing agents thereby decrease in the fixation of Cu in soils (Prasad, 1981 and Lakshmi *et al.*, 2013b). A significant positive correlation between organic matter and exchangeable Cu was also recorded by Grewal *et al*. (1969). Again, the result pointed out that statistically higher accumulation of DTPA extractable Cu in soil was perceived in T4 followed by T11 throughout the incubation period. There was a significant interaction effect between treatments and moisture on 60th and 90th day of incubation.

**Table 5. Effect of INM and moisture regimes on DTPA extractable Cu (mg kg-1) in soil**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Incubation days | | | | | | | | | | | | | | | | | | | |
| 0 | | | | 30 | | | | | | 60 | | | | 90 | | | | | |
| W1 | W2 | W3 | Mean | W1 | | W2 | | W3 | Mean | W1 | W2 | W3 | Mean | W1 | W2 | | W3 | Mean | |
| T0 | 0.95 | 0.93 | 0.94 | 0.94 | | 0.60 | 0.61 | | 0.57 | 0.59 | 0.55 | 0.53 | 0.53 | 0.54 | 0.45 | | 0.43 | 0.43 | | 0.44 |
| T1 | 0.94 | 0.94 | 0.96 | 0.95 | | 0.63 | 0.64 | | 0.60 | 0.62 | 0.59 | 0.55 | 0.57 | 0.57 | 0.49 | | 0.45 | 0.44 | | 0.46 |
| T2 | 0.93 | 0.93 | 0.95 | 0.94 | | 0.65 | 0.64 | | 0.62 | 0.64 | 0.60 | 0.61 | 0.59 | 0.60 | 0.51 | | 0.47 | 0.45 | | 0.48 |
| T3 | 0.95 | 0.93 | 0.94 | 0.94 | | 0.68 | 0.70 | | 0.65 | 0.68 | 0.62 | 0.64 | 0.60 | 0.62 | 0.50 | | 0.48 | 0.46 | | 0.48 |
| T4 | 0.95 | 0.95 | 0.95 | 0.95 | | 0.75 | 0.76 | | 0.72 | 0.74 | 0.68 | 0.66 | 0.64 | 0.66 | 0.56 | | 0.55 | 0.50 | | 0.54 |
| T5 | 0.94 | 0.94 | 0.95 | 0.94 | | 0.73 | 0.63 | | 0.61 | 0.66 | 0.60 | 0.60 | 0.59 | 0.60 | 0.48 | | 0.48 | 0.45 | | 0.47 |
| T6 | 0.93 | 0.95 | 0.94 | 0.94 | | 0.70 | 0.71 | | 0.70 | 0.70 | 0.62 | 0.61 | 0.60 | 0.61 | 0.51 | | 0.49 | 0.47 | | 0.49 |
| T7 | 0.95 | 0.96 | 0.93 | 0.95 | | 0.67 | 0.69 | | 0.64 | 0.67 | 0.61 | 0.63 | 0.61 | 0.62 | 0.51 | | 0.47 | 0.45 | | 0.48 |
| T8 | 0.93 | 0.95 | 0.95 | 0.94 | | 0.65 | 0.65 | | 0.65 | 0.65 | 0.60 | 0.63 | 0.59 | 0.61 | 0.52 | | 0.50 | 0.47 | | 0.50 |
| T9 | 0.94 | 0.92 | 0.94 | 0.93 | | 0.65 | 0.64 | | 0.63 | 0.64 | 0.61 | 0.61 | 0.58 | 0.60 | 0.50 | | 0.51 | 0.46 | | 0.49 |
| T10 | 0.94 | 0.93 | 0.94 | 0.94 | | 0.63 | 0.64 | | 0.60 | 0.62 | 0.59 | 0.62 | 0.58 | 0.60 | 0.47 | | 0.48 | 0.45 | | 0.47 |
| T11 | 0.93 | 0.93 | 0.96 | 0.94 | | 0.65 | 0.75 | | 0.70 | 0.70 | 0.62 | 0.65 | 0.62 | 0.63 | 0.53 | | 0.51 | 0.49 | | 0.51 |
| Mean | 0.94 | 0.94 | 0.95 |  | | 0.67 | 0.67 | | 0.64 |  | 0.61 | 0.61 | 0.59 |  | 0.50 | | 0.49 | 0.46 | |  |
| Source | SE(d) ± | | CD0.05 | | | SE(d) ± | | CD0.05 | | | SE(d) ± | | CD0.05 | | SE(d) ± | | | CD0.05 | | |
| T | 0.004  0.001  0.011 | | 0.007  0.002  0.022 | | | 0.003  0.001  0.008 | | 0.005  0.001  0.016 | | | 0.003  0.001  0.008 | | 0.005  0.001  0.015 | | 0.002  0.000  0.005 | | | 0.004  0.001  0.011 | | |
| W |
| T X W |

In conclusion, it is the demand of time to find out the eco-friendly organic materials to develop suitable combination with inorganic fertilizers for maintaining better soil health, soil quality, crop yield and improving nutrient use efficiency. Among the treatments, significantly higher concentration of available Zn and Mn was observed in T11 followed by T6. Further, the data pointed out that statistically higher accumulation of DTPA extractable Cu in soil was perceived in T4 followed by T11 throughout the incubation period. So, the addition of inorganic and organic manures and bio-fertilizer improve micronutrients status or content of soil. Therefore, the effect of INM on the extractability of micro-nutrient elements deserves special attention.

**REFERENCES**

Abdul Salam, M. and Subramanian, S. (1988). *Ind. J. Agric. Sci*., 58: 190 – 193.

Angelova, V.R., Akova, V.I., Artinova, N.S. and Ivanov, K.I. (2013). The effect of organic amendments on soil chemical characteristics. *Bulg. J. Agric. Sci.,* 19: 958-971

Baishya, L.K., Sarkar, D., Ansari, M.A., Singh, K.R., Meitei, C.B. and Prakash, N. (2015). Effect of micronutrients, organic manures and lime on bio-fortified rice production in acid soils of Eastern Himalayan region. *Eco. Env. & Cons.,* 22(1): 199-206.

Balwinder, K., Gupta, R.K. and Bhandari, A.L. (2008). Soil fertility changes after long-term application of organic manures and crop residues under rice-Wheat system*. J. Ind. Soc. Soil Sc., 56* (1): 80-85.

Baitilwake, M.A., Salomez, J., Mrema, J.P. and Neve, S.D. (2012). Nitrogen mineralization of two manures as Influenced by Contrasting Application Methods under Laboratory conditions. *Commun. Soil Sci. Plant Anal*., 43(1-2): 357-367.

Baran,W.(2001). The effect of grape marc as growing medium on growth of hypostases plant. Bioresour.Technol.,78:103-106.

Chaudhary, M., Singh, B.R., Krogstad, T. and Heim, M. (2011). Release of Copper, Zinc, and Manganese from Rock Powder with Organic Materials Applied to Soils. *Comm. Soil Sci. Plant Anal.* 42: 2682–2697.

Choudhary, A.K., Thakur, R.C. Kumar,N.. (2008). Effect of integrated nutrient management on soil physical and hydraulic properties in rice-wheat crop sequence in NW Himalayas.Indian Journal.of Soil Conservation, 36(2):97-104.

Das, D.K. and Mandal, L.N. (1986). In: Micronutrients: Their Behaviour in Soils and Plants (D. K. Das, ed.) pp. 47 – 126, Kalyani Publishers, New Delhi-110002.

Dhaliwal, S.S., Walia, M.K. and Phutela, R.P. (2012). Effect of inorganic fertilizers and manures application on macro and micronutrients distribution under long term rice-wheat system. *J. Plant Sci. Res.* 28 (1): 149-161.

Garai, T.K., Datta, J.K. and Mondal, N.K. (2014). Evaluation of integrated nutrient management on *boro* rice in alluvial soil and its impacts upon growth, yield attributes, yield and soil nutrient status. Archives *Agron. Soil Sci*. 60(1): 1-14.

Gautam, P., Sharma, G.D., Rana, R., Lal, B. (2013). Effect of integrated nutrient management and spacing on growth parameters, nutrient content and productivity of rice under system of rice intensification. *Inter. J. Res. Biosci.* 2(3):53-59.

Gomez, K.A. and Gomez, A.A.(1984).Statistical Procedure for Agricultural Research, Published by John Willey &Sons, New York.Pp.630.

Grewal, K.S., Singh, D., Mehta, S.C. and Karwasra, S.P. (1990). Effect of long-term fertilizer application on physiochemical properties of soils. *J. Ind. Soc. Soil Sci.* 47(3): 538-514.

Haldar, M. and Mandal, L.N. (1979). Influence of soil moisture regimes and organic matter application on the extractable Zn and Cu content in rice soils. *Plant soil* .53(1): 203-213.

Helgason, B.L., Larney, F.J., Janzen, H.H. and Olson, B.M. (2007). Nitrogen dynamics in soil amended with composted cattle manure. *Can. J. Soil Sci.* 87(1): 43 – 50.

Jat, L.K. and Singh, Y.V. (2017). Short-term Effects of Organic and Inorganic Fertilizers on Soil Properties and Enzyme Activities in Rice Production. *Int.J.Curr.Microbiol.App.Sci 6*(2): 185-194.

Lakshmi, C.S.R., Rao, P.C., Sreelatha, T., Padmaja, G., Madhavi, M., Rao, P.V. and Sireesha, A. (2013a). Effect of integrated nutrient management (INM) on humic substances and micronutrient status in submerged rice soils. *J. of Rice Res.*, 6(1): 57-65.

Lakshmi, C.S.R., Rao, P.C., Sreelatha, T., Padmaja, G., Madhavi, M. and Sireesha, A. (2013b). Effect of different vermicomposts under integrated nutrient management on soil fertility and productivity of rice. *Oryza*, 50(3): 241-248.

Lekasi, J.K. Ndung’u K.W., Kifuko ,M.N.,(2005). Organic Resource Management in Kenya. Perspective and Guidelines Forum for Organic Resource Management and Agricultural Technologies (FORMAT).

Patel, U.K. and Tiwari, J.K. (2018). Effect of organic and inorganic fertilizer nutrient on yield of soybean crop. *Int. J. Curr. Microbiol. App. Sci.,* 7: 392-396.

Prasad, B. (1981). Use of organic manure for correlation of zinc and iron deficiency in maize plant grown on calcareous soils. *J. Indian Soc. Soil Sci.*, 29: 132-133.

Safarzadeh, E., Kasmae, L.S. and Abadi, Z.A. (2018). Effect of organic substances on iron-release kinetics in a calcareous soil after basil harvesting S. *J. Serb. Chem. Soc*. 83 (0) 1–12.

Swarup, A. and Yaduvanshi, N.P.S. (2000). Effects of integrated nutrient management on soil properties and yield of Rice in alkali soils. *J. Ind. Soc. Soil Sci*. 48(2): 279-282.

Zeid, H.A., Wafaa, H.M., Abou El Seoud, I.I. and Alhadad, W.A.A. (2015). Effect of organic materials and inorganic fertilizers on the growth, mineral composition and soil fertility of radish plants (*Raphanus sativus*) grown in sandy soil. *Middle East J. Agril. Res.*, 4(1): 77-87.