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# Mobility of Toxic Elements in Crop and Agricultural Soil Treated with Municipal Sewage Sludge

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**Abstract:** The toxic metal absorption in radish crop and soil treated with sewage sludge in research plot in Allahabad Agricultural Institute –Deemed University, Allahabad have been studied to evaluate the absorption of toxic metal. Sewage sludge used in this study has high contents of both organic matter and nutrients (N, P and K) and none of the heavy metals were found over the maximum established limits. This soil is suitable for growing crops as none of the metals were absorbed above permissible limit. When the sludge was added to the soil, some of the physico-chemical parameters are modified which affects the absorption of toxic metals. When the sewage sludge was used with fertilizers it has given good response in respect of nutrient content and production. There was no phytotoxicity level on the plant growth treated with municipal sewage sludge, due to cumulative accumulation and also high bioavailability of metals; plant metal content exceeds safety food metal limits. It can be seen that heavy metals could be passed to higher levels in the course of time by successive applications of municipal sewage sludge of agronomic rates and thus it could be inevitable to suffer the irreversible problems of cumulative loading of trace elements and in any type of soil in long term effect. However, the agricultural use of this sludge should be well controlled, bearing in mind environmental criteria, because of the persistence of metals in the soil.

**Key words:** Absorption, reclamation, soil and sewage sludge.

## Introduction

As tendency increases with time to favour land application over other means of disposal of municipal sewage sludge that have characteristics potentially beneficial for agriculture (the 'beneficial use' philosophy) despite the fact these wastes may have other properties undesirable for agriculture or may contain significant concentrations of numerous contaminants. The sewage sludge contains plant nutrients and organic matter; it may be used to supplement or replace commercial fertilizers for crop production (Wang et al., 2001). Land application of contaminated waste products has been defended as beneficial use by some scientists and regulators, based on the premise that the behaviour of any toxins accumulated in soils from this practice is reasonably well understood and will not have detrimental agronomic or environmental impacts into the foreseeable future.

The beneficial effects of using sewage sludge in agriculture have been proven by numerous studies. These have shown that the application of sewage sludge improves the physical, chemical, and biological properties of the soil (Mantovia et al., 2005; Benitez et al., 2001; Aggelides and Londra, 2000) and increases crop production through the addition of nutrients and organic matter (Mantovia et al., 2005; Akrivos et al., 2000; Du Preez et al., 2000; Vasseur et al., 1999; Marx et al., 1995). Wei and Liu (2005) used sewage sludge compost in their experiments. Toxic metals

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contamination in the environment become a worldwide problem that affects crop yields, soil biomass and fertility, and leads to bioaccumulation of metals in the food chain (Bhargava et al., 2012). Sewage sludge discharged from municipalities containing a huge amount of toxic metals. The application of sewage sludge on land for crop cultivation offers an environmentally acceptable and favourable to agronomical means of waste disposal. There is an increasing interest in the agricultural application of sludge, due to the possibility of recycling valuable components: N, P and other plant nutrients (Smith, 1994; Wong et al., 2001).

The sludge contains large amounts of nitrogen and phosphorus; it can also replenish organic matter levels with beneficial effect on physical and biological conditions (Hall et al., 1986). However, it has long been recognized that toxic elements in the sludge may pose a risk to plant and human health. On the other hand, there are concerns about the presence of certain toxic elements in the sludge. The application of sludges in agriculture may lead to a risk for humans and the environment as a result of heavy metals and toxic organic compounds accumulating to levels high enough to cause damage (Mamais et al., 2000). The determination of metals in sewage sludge is a necessary requirement for sludge disposal or application to farmland, because there is a risk of toxic elements accumulation in the soil (Alvarez et al., 2002). The sewage sludge used as agricultural fertilizer is a major problem for crop and environmental qualities and their impact on human health, because of the presence of various toxic metals; they are persistent for a long time in soil due to their immobile nature. Nutrients present in sewage sludge may increase the plant biomass and yield. The variable nature and concentrations of trace elements are largely dependent on the type and amount of urban and industrial discharges (Bose and Bhattacharyya, 2007).

The determination of metals in sewage sludge is an important requirement for sludge disposal or application to farmland, because there is a risk of toxic elements accumulating in the soil. The increased concentration of heavy metals in soil due to sewage sludge amendment led to increases in heavy metal uptake and shoots and root concentrations of Ni, Cd, Cu, Cr, Pb and Zn in plants as compared to those grown in amended soil. Accumulation was more in the roots than shoots for most of the heavy metals. The transformations of metals from biosolids to soil and subsequently to plants pose potential health risks because they can enter the food chain and the environment. Baker (1981) has distinguished three types of plant, viz. accumulator, excluders and indicator plants. In accumulator plants the concentration ratio of the element in the plant to that in the soil is >1. In excluder plant metal concentrations in aerial parts are maintained low (<<1) and constant over a wide range of soil concentrations. In indicator plants the uptake and transport of metals are regulated in such a way that the ratio of the concentration of elements in the plant to that in the soil is near 1. In the present study, we focused on the radish crop that were grown on different amendment of soils and fertilizers with municipal sludge to assess the translocation of metals and its effects on the growth of plants.

## Materials and Methods

The site for this investigation was selected at the research farm in college of forestry and environmental science, SHIATS, Allahabad. Allahabad is located in the south-eastern part of Utter Pradesh at an elevation of 78 metres from the sea level. The climate is basically sub-tropical with extreme of winter and summer. During summer the temperature rises up to 48˚C whereas during winter it is sometimes as low as 1.8°C, occasionally frost is also seen. During summer, the southern extreme dry hot strong wind is a common feature. The average rainfall of Allahabad is about 50 cm, which is concentrated during the period of July to September. Occasional rains during winter may also be received. The extraction and analysis of the selected samples was done in Environmental Science Laboratory, College of Forestry, SHIATS, Allahabad.

### Sampling of Soil and Untreated Domestic Sewage Sludge

Soil samples were collected from each of the plots. The soil samples were collected at the depths 0-15 cm and 15-30 cm with the help of a stainless steel tube auger. The representative soil samples were transferred into tight polyethylene bags and brought into the laboratory. The soil samples were dried at 40°C for 48 hours, in the hot air oven and crushed to pass through a 2 mm nylon sieve. A di-acid mixture was used to find out the toxic metals Cd and Pb in the soil. A known amount (5 gm) oven dry soil was weighed and transferred into 100 ml beaker to which 25 ml of conc. $HNO_3$ and perchloric acid was added. 25 ml conc. $HNO_3$ and 5 ml of $HClO_4$ (5:1). The mixture was placed on a hot plate at 105°C for 1 hour until the sample was completely dry. After cooling, the solution was mixed and filtered through Whatman no. 42 filter paper into a 50 ml volumetric flask. The digested samples were then analysed for Cd and Pb on AAS (Atomic Absorption Spectrophotometer). Available nitrogen in soil was determined by the Kjeldahl Method (Subbian and Asija, 1956). Available phosphorous was determined by OLSEN spectrophotometric method and available potassium by flame photometric method (Jackson, 1973). The sewage sludge was brought from sewage treatment plant, Naini. After homogenization and drying three portions were taken, digested with a nitric Perchloric solution and toxic element concentrations were determined by Atomic Absorption Spectrophotometer.

### Physicochemical Studies

The physicochemical parameters for the soil and sewage sludge samples—pH, EC, organic carbon (OC), available nitrogen, available phosphorous, available potassium and heavy metals (Pb, Cd, Zn) contents—were measured by standard methods (Table 1). The pH was determined for each batch, using a ratio of wastewater sludge to ultra-pure water of 1:2 (w/v). The OC was measured by the Walkeley-Black method. It was oxidised to carbon dioxide with potassium dichromate in the presence of sulphuric acid. The unreacted potassium dichromate was titrated with iron (II) sulphate. Blanks were run simultaneously.

**Table 1: Chemical analysis of sewage sludge**

| *Parameters* | *Value* |
|---|---|
| pH (1:2) w/v | 6.10 |
| EC (1:2) ($dsm^{-1}$) | 1.89 |
| Organic carbon (%) | 2.81 |
| Available nitrogen (kg/ha) | 754.47 |
| Available phosphorous (kg/ha) | 87 |
| Available potassium (kg/ha) | 525 |
| Cd (ppm) | 390 |
| Pb (ppm) | 392 |
| Zn (ppm) | 4.960 |

### Experimental Details

The experiment was laid out in a 3 × 3 factorial design with five levels of sewage sludge and three levels of fertilizers and their combinations. The treatment was replicated three times and were allocated randomly in each replication. Total number of plots will be 45 having an area of 2 $m^2$, so the net cultivated area will be 90 $m^2$. Details of treatment combination are given in Table 2.

**Table 2: Treatment and their combination**

| *Treat-ment* | *Combination* | *Description* |
|---|---|---|
| $T_0$ | $I_0$ S0 | 0% RDF + 0 kg sewage sludge |
| $T_1$ | $I_0$ S1 | 0% RDF + 6 kg sewage sludge |
| $T_2$ | $I_0$ S2 | 0% RDF + 12 kg sewage sludge |
| $T_3$ | $I_0$ S3 | 0% RDF + 18 kg sewage sludge |
| $T_4$ | $I_0$ S4 | 0% RDF + 24 kg sewage sludge |
| $T_5$ | $I_1$ S0 | 50% RDF + 0 kg sewage sludge |
| $T_6$ | $I_1$ S1 | 50% RDF + 6 kg sewage sludge |
| $T_7$ | $I_1$ S2 | 50% RDF + 12 kg sewage sludge |
| $T_8$ | $I_1$ S3 | 50% RDF + 18 kg sewage sludge |
| $T_9$ | $I_1$ S4 | 50% RDF + 24 kg sewage sludge |
| $T_{10}$ | $I_2$ S0 | 100% RDF + 0 kg sewage sludge |
| $T_{11}$ | $I_2$S1 | 100% RDF + 6 kg sewage sludge |
| $T_{12}$ | $I_2$ S2 | 100% RDF + 12 kg sewage sludge |
| $T_{13}$ | $I_2$ S3 | 100% RDF + 18 kg sewage sludge |
| $T_{14}$ | $I_2$ S4 | 100% RDF + 24 kg sewage sludge |

$I_1$ = 50% Recommended Dose Fertilizer (RDF)
$I_2$ = 100% Recommended Dose Fertilizer

## Result and Discussion

The data presented in Table 3 revealed the effect on chemical properties (pH, EC) of soil under different treatment combinations. Max. pH and EC after harvesting were 7.9 and 0.48 observed in T1, T6 , T11 (0-15 cm) and T14 (0-15 cm). Min. pH and EC after harvesting were 7.2 and 0.22 observed in T14 (0-15 cm) and T11 (0-15 cm). There was a significant effect due to sewage sludge on pH (0-15 cm) and EC (15-30 cm) under different treatment combination in comparisons with pre sowing pH (0-15 cm) and EC (15-30 cm) were 7.8 and 0.59 resp. and non-significant effect on pH (15-30 cm) and EC (0-15 cm). There was non-significant effect due to fertilizer on pH and EC.

Max Zn in root and leaves were 3.980 $mgkg^{-1}$ and 3.235 $mgkg^{-1}$ found in $T_{14}$ ($I_2S_4$) respectively. Min Zn in root and leaves were 2.243 $mgkg^{-1}$ and 3.235 $mgkg^{-1}$ found in $T_{14}$ ($I_2S_4$) respectively. There was a significant effect due to sewage sludge under different treatment combination of Zn concentrations in leaves and roots of radish crop. There was a significant effect due to fertilizer under different treatment combination of Zn concentrations in leaves and non-significant effect on Zn in roots of radish crop.

Max. Zn and Cd in sewage treated soil were 4.957 $mgkg^{-1}$ and 44 $mgkg^{-1}$ found in $T_{14}$ ($I_2$ $S_4$), $T_9$ ($I_1$ $S_4$) and $T_4$ ($I_0$ $S_4$). Min. Zn and Cd in sewage treated soil were 4.957 $mgkg^{-1}$ and 44 $mgkg^{-1}$ found in $T_{14}$ ($I_2$ $S_4$), $T_9$ ($I_1$ $S_4$) and $T_4$ ($I_0$ $S_4$). The acidic pH could serve to

**Table 3: Effect of different levels of recommended dose of fertilizers (inorganic fertilizer NPK) and treated with sewage sludge on pH (1:2) w/v and EC (dsm$^{-1}$) of soil**

| *Treatment combination* | *pH (1:2) w/v* | | *$EC_{25\,c}$ (dSm$^{-1}$)* | |
|---|---|---|---|---|
| Depth | (0-15 cm) | (15-30 cm) | (0-15 cm) | (15-30 cm) |
| Pre Sowing | 7.8 | 8.14 | 0.46 | 0.59 |
| After harvesting | | | | |
| T0 I0S0 | 7.5 | 7.3 | 0.24 | 0.18 |
| T1 I0S1 | 7.9 | 7.7 | 0.31 | 0.29 |
| T2 I0S2 | 7.5 | 7.6 | 0.39 | 0.36 |
| T3 I0s3 | 7.3 | 7.5 | 0.40 | 0.32 |
| T4 I0S4 | 7.3 | 7.5 | 0.42 | 0.33 |
| T5 I1S0 | 7.64 | 7.5 | 0.36 | 0.29 |
| T6 I1S1 | 7.9 | 7.6 | 0.44 | 0.28 |
| T7 I1S2 | 7.4 | 7.5 | 0.40 | 0.32 |
| T8 I1S3 | 7.3 | 7.5 | 0.42 | 0.33 |
| T9 I1S4 | 7.3 | 7.43 | 0.45 | 0.41 |
| T10 I2S0 | 7.6 | 7.65 | 0.40 | 0.31 |
| T11 I2S1 | 7.9 | 7.6 | 0.39 | 0.25 |
| T12 I2S2 | 7.4 | 7.6 | 0.38 | 0.27 |
| T13 I2S3 | 7.3 | 7.5 | 0.46 | 0.36 |
| T14 I2S4 | 7.2 | 7.4 | 0.48 | 0.43 |
| F Test (S) | S | NS | NS | S |
| S.E.m (S) | 0.00529 | - | - | 0.0529 |
| C.D. (S) at 5% | 0.0888 | - | - | 0.0984 |
| F Test (F) | NS | NS | NS | NS |

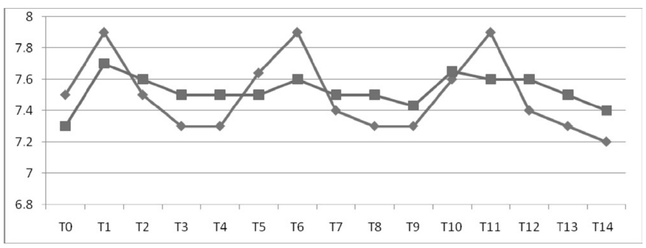


**Figure 1: pH variation for different treatment combination of amended soil after harvesting.**

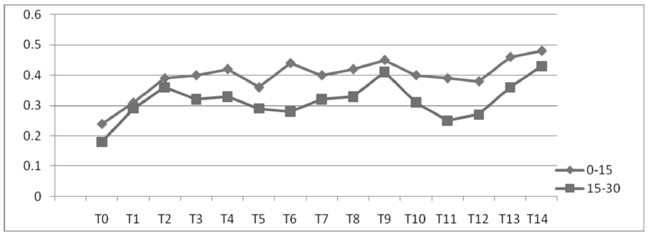


**Figure 2: EC variation for different treatment combination of amended soil after harvesting.**

increase metal mobility through a decrease in available binding sites on soil colloids because protons and hydroxyl ions compete for soil adsorption and/or complexation sites (Pierzynsky et al., 1994) There was significant effect due to sewage sludge under different treatment combination in comparison with pre-sowing, Zn was 2.425 mgkg$^{-1}$ and Cd was not detectable as pre-sowing. This revealed, as influenced in Zn and Cd pre-sowing change, after harvesting. There was a non-significant effect due to fertilizer under different treatment.

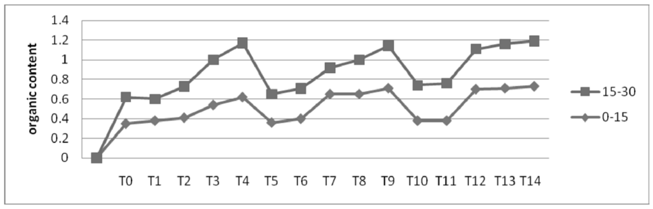


**Figure 3: Effect of different treatment combination of amended soil on organic content of soil.**

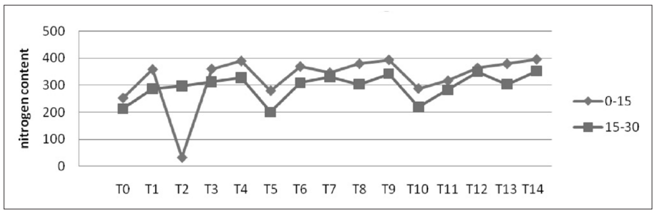


**Figure 4: Effect of different treatment combination of amended soil on nitrogen content of soil.**

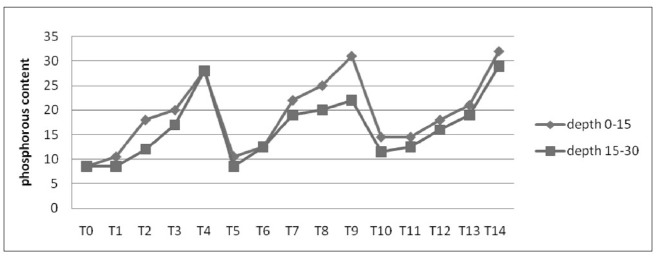


**Figure 5: Effect of different treatment combination of amended soil on phosphorous content of soil.**

**Table 4: Effect of different levels of recommended dose of fertilizers (inorganic fertilizer NPK) and treated with sewage sludge on chemical properties (organic carbon, NPK) of soil**

| *Treatment combination* | *Organic carbon (%)* | | *Nitrogen (kgha$^{-1}$)* | | *$P_2O_5$ (kgha$^{-1}$)* | | *$K_2O$ (kgha$^{-1}$)* | |
|---|---|---|---|---|---|---|---|---|
| | 0-15 cm | 15-30 cm | 0-15 cm | 15-30 cm | 0-15 cm | 15-30 cm | 0-15 cm | 15-30 cm |
| To I0S0 | 0.35 | 0.27 | 252.65 | 212.97 | 8.51 | 8.51 | 207.00 | 204.00 |
| T1 IoS1 | 0.38 | 0.22 | 358.46 | 286.92 | 10.51 | 8.51 | 302.5 | 294.5 |
| T2 IoS2 | 0.41 | 0.32 | 32.00 | 296.45 | 18.00 | 12.00 | 314.5 | 306.5 |
| T3 Ios3 | 0.54 | 0.46 | 360.24 | 312.49 | 20.00 | 17.00 | 313.00 | 207.00 |
| T4 IoS4 | 0.62 | 0.55 | 389.66 | 328.00 | 28.00 | 28.00 | 416.00 | 313.00 |
| T5 I1So | 0.36 | 0.29 | 279.68 | 200.00 | 10.51 | 8.51 | 321.5 | 217.00 |
| T6 I1S1 | 0.4 | 0.31 | 369.42 | 309.00 | 12.51 | 12.51 | 332.5 | 234.00 |
| T7 I1S2 | 0.65 | 0.27 | 346.29 | 331.00 | 22.00 | 19.00 | 355.5 | 290.5 |
| T8 I1S3 | 0.65 | 0.35 | 379.39 | 303.00 | 25.00 | 20.00 | 324.00 | 290.5 |
| T9 I1S4 | 0.71 | 0.43 | 394.00 | 342.00 | 31.00 | 22.00 | 447.00 | 299.00 |
| T10 I2S0 | 0.38 | 0.36 | 287.74 | 219.45 | 14.51 | 11.51 | 321.5 | 290.5 |
| T11 I2S1 | 0.38 | 0.38 | 316.72 | 282.92 | 14.51 | 12.51 | 364.5 | 312.00 |
| T12 I2S2 | 0.7 | 0.41 | 364.29 | 350.00 | 18.00 | 16.00 | 376.5 | 318.00 |
| T13 I2S3 | 0.71 | 0.45 | 379.39 | 303.00 | 21.00 | 19.00 | 429.00 | 345.5 |
| T14 I2S4 | 0.73 | 0.46 | 396.00 | 352.17 | 32.00 | 29.00 | 516.00 | 351.5 |
| F Test (S) | S | S | S | S | S | S | S | NS |
| S.E.m (S) | 0.0781 | 0.0645 | 21.893 | 19.862 | 2.4494 | 3.387 | 33.6518 | - |
| C.D.(S) at 5% | 0.1452 | 0.1200 | 40.7215 | 36.944 | 4.556 | 6.2938 | 62.5925 | - |
| F Test (F) | S | NS | NS | NS | S | NS | S | S |
| S.E.m (S) | 0.0469 | - | - | - | 1.4696 | - | 20.1911 | 24.65 |
| C.D.(F) at 5% | 0.0872 | - | - | - | 2.733 | - | 37.55 | 45.8495 |

## Summary and Conclusion

Sewage sludge used in this study have high content of both organic matter and nutrients (NPK) and none of the heavy metals were absorbed over the maximum established limits in soil. This soil is suitable for growing crops as none of the metals were absorbed above established permissible limit. When the sludge was added to the soil, some physico-chemical parameters are modified and probably this modification also affects the absorption of toxic metals. When the sewage sludge was used with fertilizer it has given good response in respect to nutrient content and production. There was no phototoxicity level on the plant growth treated with municipal sewage sludge, due to cumulative accumulation and also high bioavailability of metals; plant metal content exceeds safety food metal limits.

It can be seen that heavy metals could be reached to higher levels in the course of time by successive applications of municipal sewage sludge of agronomic rates and thus it could be inevitable to meet the irreversible problems of cumulative loading of trace elements and in any type of soil in long term effect. Nevertheless, the agricultural use of this sludge should be well controlled, bearing in mind environmental criteria, because of the persistence of metals in the soil.

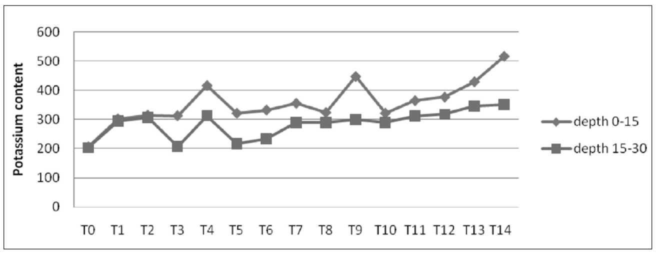


**Figure 6: Effect of different treatment combination of amended soil on potassium content of soil.**

**Table 5: Absorption of toxic metals in the leaves and root of radish crop grown in municipal sewage sludge soil**

| Treatment combination | Cd $mgkg^{-1}$ Leaves/Root | Pb $mgkg^{-1}$ Leaves/Root | Zn $mgkg^{-1}$ Leaves/Root |
|---|---|---|---|
| T0 I0S0 | - | - | 1.986 2.243 |
| T1 I0S1 | - | - | 2.027 3.462 |
| T2 I0S2 | - | - | 2.594 2.499 |
| T3 I0s3 | - | - | 2.022 3.673 |
| T4 I0S4 | - | - | 3.283 3.875 |
| T5 I1So | - | - | 2.023 2.564 |
| T6 I1S1 | - | - | 1.748 3.462 |
| T7 I1S2 | - | - | 2.442 2.523 |
| T8 I1S3 | - | - | 1.968 3.674 |
| T9 I1S4 | - | - | 3.016 3.884 |
| T10 I2S0 | - | - | 2.027 2.454 |
| T11 I2S1 | - | - | 1.954 3.248 |
| T12 I2S2 | - | - | 2.654 2.334 |
| T13 I2S3 | - | - | 2.054 3.498 |
| T14 I2S4 | - | - | 3.285 3.980 |
| F Test (S) | - | - | S S |
| S.E.m (S) | - | - | 0.1290 0.2236 |
| C.D.(S) at 5% | - | - | 0.2401 0.4159 |
| F Test (F) | - | - | S NS |
| S.E.m (F) | | | 0.0774 |
| C.D.(Fr) at 5% | | | 0.144 |

**Table 6: Absorption of toxic metals in the soil treated with municipal sewage sludge**

| Treatment combination | Cd $mgkg^{-1}$ | Pb mg $kg^{-1}$ | Zn $mgkg^{-1}$ |
|---|---|---|---|
| Pre Sowing | - | - | 2.425 |
| T0 I0S0 | - | - | 2.425 |
| T1 I0S1 | 1.6 | - | 1.672 |
| T2 I0S2 | 3.9 | - | 3.381 |
| T3 I0s3 | 9.3 | - | 4.938 |
| T4 I0S4 | 44 | - | 4.945 |
| T5 I1So | - | - | 2.673 |
| T6 I1S1 | 1.6 | - | 1.672 |
| T7 I1S2 | 3.9 | - | 3.38 |
| T8 I1S3 | 9.3 | - | 4.943 |
| T9 I1S4 | 44 | - | 4.946 |
| T10 I2S0 | - | - | 2.537 |
| T11 I2S1 | 1.6 | - | 1.515 |
| T12 I2S2 | 3.9 | - | 3.355 |
| T13 I2S3 | 9.3 | - | 4.047 |
| T14 I2S4 | 44 | - | 0.0011 |
| F Test (S) | S | - | 0.1694 |
| S.E.m (S) | 0.0223 | - | 0.0011 |
| C.D.(S) at 5% | 0.0414 | - | 0.1694 |
| F Test (F) | NS | - | NS |

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