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Assessment of Nutrients and Heavy Metals (HM) Uptake in Golden Rod Treated with Sewage Sludge

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ABSTRACT

Purpose- *Pot culture experiment was carried out at Horticulture farm, ANGRAU- Hyderabad to assess the nutrients and heavy metals (hm) uptake in golden rod treated with sewage sludge*

Methods- *Sewage sludge obtained from NMK-STP, Hyderabad analysed for physico-chemical properties and used in the study along with Red soil in different fractions. A total of seven potting media were prepared containing soil, sewage sludge and different ratios of soil + sewage sludge. Plant and spike samples were analysed for nutrients and heavy metals uptake.*

Results- *The physico-chemical and biological characteristics of sewage sludge presented in the Table 1., indicated that sewage sludge can be safly used as a rich organic matter for realizing Golden Rod yield instide of inorganic fertilizers with ecofriendlly manners. Highest uptake of major nutrients (NPK), micronutrient (Zn) and heavy metal like Ni were within maximum permissible limits either in spikes or plants of Golden Rod in 100% sewage sludge treatment (T_5). Uptake of heavy metals viz., Pb, Ni, Co and Cd in spikes were within the maximum permissible limits as per WHO standards (WHO, 1996).*

Key words- Golden Rod, Heavy metals, Waste management, Sewage sludge and Nutrients.

I. INTRODUCTION

Sewage sludge has long been considered to be a nuisance for environmental control. Increasingly stringent environmental regulate-ons and industrial growth have increased the disposal requirements. Therefore, disposal of sludge from wastewater treatment plants (WWTPs) is a problem for any municipality. Ocean dumping has been prohibited in many countries. Landfilling and spreading on reclaimed land are the most current sludge disposal methods worldwide. Some cities on the coastline even convey the sludge out to sea in pipes. In general, land disposal is the cheapest way of disposing of sludge if it enables crops to be grown on poor land for agricultural purposes. The problem of sludge disposal will intensify as the amount of sludge produced increases. One major constraint in land application of sewage sludge for soil amendment is the potential metal accumulation in crops which in turn will transfer up to food chain posing a potential health hazard to human beings (Sims and Kline, 1991).

The objective of this study, therefore, was to investigate the effect of sewage sludge on nutrients and HM uptake in Golden Rod to combat the scarcity of chemical fertilizers and their negative residual impact on soil phisico-chemical properties.

Results indicated that sewage sludge can be safly used as a rich organic matter for realizing Golden Rod yield instide of inorganic fertilizers with ecofriendlly manners. Among treatments, T_5 (100% sewage sludge) was found to be significantly supirior in all observed parameters, however the HM uptake in these treatment were within meximum permisible limites.

II. MATERIALS AND METHODS

2.1 Study site- A pot culture experiment was conducted on alfisols (red soil) at green house farm of the Department of Horticulture, College of Agriculture, Rajendranagar, Hydeabad during kharif 2013 to study the innovative approache of effect of sewage sludge application on nutrients and HM uptake in Golden Rod.

2.2 Treatments- The experiment was laid out in Completely Randomized Design (CRD) with three replications and necessary data was collected whenever required. There were seven treatments consisting of T_1 (20% sewage sludge), T_2 (40% sewage sludge), T_3 (60% sewage sludge), T_4 (80% sewage sludge), T_5 (100% sewage sludge), T_6 (RDF - Inorganic N, P and K @ 100, 100 and 100 kg ha^{-1}, respectively) and T_7 (Control).

2.3 Experimental protocol- Before starting of experiment the silent properties of sewage sludge were analysed using standard methods, which are presented in the Table 1.

2.4 Sewage Sludge Chemical Analysis- Sewage sludge used in the pot culture experiment was analyzed for physico-chemical and biological properties by using standard procedures. The pH was determined in 1:10 sewage sludge (1 mm sieved) and water suspension by using combined glass electrode pH meter (Jackson, 1973). Electrical conductivity was determined in 1:20 sewage sludge and water suspension by using Electrical Conductivity meter (Jackson, 1973) and expressed in dS m^{-1}. Organic carbon content of sewage sludge was estimated by the wet digestion method (Walkley and Black, 1934). Nitrogen content of the sewage sludge was determined following Bremner (1965) method.

2.4.1 Digestion of Sewage Sludge for P, K and Zn- Finely ground sample (0.5 gm) was digested with 20 ml triacid mixture consisting of HNO_3: H_2SO_4: $HClO_4$ in 9:4:1. The digest was kept on the hot plate for about two hours at 160^OC, until a clear digest was obtained. The intensity of yellow colour was determined by using double beam UV Spectrophotometer model UV5704SS at 420 nm (Piper, 1966). The potassium content in the triacid digest was determined by using Flame photometer model CL 361(Jackson, 1973). Zinc in the triacid extract was determined by using the Atomic Absorption Spectrophotom-eter (AAS) model NOVAA300 and expressed as mg kg^{-1} (Lindsay and Norwell, 1978).

2.4.2 Digestion of sewage sludge for HM (Cd, Co, Ni and Pb)- Finely ground sample (1 gm) was digested with 20 ml diacid mixture consisting of HNO_3: $HClO_4$ in 9:4. The digest was kept on the hot plate for about two hours at 160^OC, until a clear digest was obtained. The diacid extract was used for analysis of HM (Cd, Co, Ni and Pb) using the Atomic Absorption Spectrophotometer (AAS) model NOVAA300 and expressed as mg kg^{-1} (Swarajya et al., 2010).

2.4.3 Sludge volume index (SVI)- The sludge volume index is the volume in milliliters occupied by one gram of a suspension after 30 minutes settling (Dick and Vesilind, 1969). SVI determined through used standard laboratory test method (Davis et al., 2008). The procedure involves measuring the Mixed Liquor Suspended Solids (MLSS) value and also the sludge settling rate.

$$\textbf{SVI}\ (\text{mL g}^{-1}) = \frac{\text{SSV (mL L}^{-1})}{\text{MISS (mg L}^{-1})} \times 1000$$

2.5 Chemical analysis of plant and spike- Plant **s**amples collected for recording dry matter production (DMP) at 45 and 90 days after transplanting (DAT) were dried, powdered and utilized for chemical analysis.

2.5.1 Nitrogen uptake-For estimation of nitrogen in plant sample, 0.1 g of plant sample was added with conc. H_2SO_4. Later it was heated on flame by adding H_2O_2 (hydrogen peroxide) drop wise till it became colourless. The extract obtained was used to estimate nitrogen concentration in plant samples by using Kjelplus. The concentration was calculate in per cent and further expressed in g plant^{-1} using following formula.

$$\textbf{N uptake (g plant}^{-1}\textbf{) = N content (\%) x DMP (g plant}^{-1}\textbf{)/100}$$

3.5.2 Wet digestion- Diacid digestion was carried out using 9:4 mixture of HNO_3 and $HClO_4$. One gram of pounded plant material was taken into 100 ml volumetric flask and 10 ml of diacid mixture was added to this flask and mixed by swirling. The extract was finally made up to 100 ml with double distilled water, filtered and suitable aliquots were used for estimation of the P, K, Zn, Cd, Co, Ni and Pb.

3.5.3 Phosphorus uptake- The phosphorus concentration in plant samples was determined by Vanado molybdo phosphoric yellow colour method (Piper, 1966). The intensity of the yellow colour was read using spectro-photometer (Model UV 5704SS).

3.5.4 Potassium uptake- The potassium concentration in plant samples was estimated by using flame photometer Model Elico CL 361 (Piper, 1966).

3.5.5 Zinc uptake- Zinc in the filtrate was determined using Atomic Absorption Spectrophotometer (AAS) and expressed in mg plant^{-1}.

$$\textbf{Zn uptake (mg plant}^{-1}\textbf{) = Zn content (}\mu\textbf{g g}^{-1}\textbf{) x DMP (g plant}^{-1}\textbf{)/1000}$$

3.5.6 HM uptake- HM (Cd, Co, Ni and Pb) in the filtrate were determined using Atomic Absorption Spectrophotometer (AAS) and expressed in mg plant^{-1}.

$$\textbf{HM uptake (mg plant}^{-1}\textbf{) = HM content (}\mu\textbf{g g}^{-1}\textbf{) x DMP (g plant}^{-1}\textbf{)/1000}$$

Table 1. Silent properties of Sewage Sludge

Parameters	Units	Sewage Sludge
Physio-chemical properties		
Soil reaction	pH	5.81
EC	dS m^{-1}	5.48
OC	%	25.76
Total major nutrient status		
Nitrogen	%	3.29
Phosphorus	%	1.23
Potassium	%	2.98

Micro nutriente		
Zinc	mg kg^{-1}	27.72
Total heavy metals		
Cadmium	mg kg^{-1}	0.97
Cobalt	mg kg^{-1}	0.37
Nickel	mg kg^{-1}	1.69
Lead	mg kg^{-1}	6.86
SVI	mL g^{-1}	482.71

2.6 Statistical Analysis- The results of pot culture study were subjected to statistical analysis as per the procedures outlined by Snedcor and Cochran (1967).

III. RESULTS AND DISCUSSION

3.1 Physico-chemical properties of sewage sludge-

The sewage sludge was moderately acidic with pH of 5.81. It was slightly saline with EC value of 5.48 dS m^{-1}. Organic carbon was high (27.76%) and SVI was 482.71 mL g^{-1}. The available total nutrients viz., N, P and K in sewage sludge were 3.29, 1.23 and 2.98%, respectively. The N, P and K content of sewage sludge was more by 6.58, 6.15 and 5.96 times, respectively than Farm Yard Manure and compared with urban compost, available N, P and K was more by 6.58, 2.46 and 2.98 times, respectively. The triacid extractable zinc of sewage sludge was 27.72 mg kg^{-1} which was within the maximum permissible limits as per USEPA standards, 1993.

3.1.1 Diacid extractable HM (Cd, Ni, Co and Pb)- The diacid extractable contents of HM Cd, Ni, Co and Pb were 0.97, 1.69, 0.37 and 6.86 mg kg^{-1}, respectively. The heavy metal contents were within the maximum permissible limits. (USEPA , 1993 and Water Research Commission 1997).

3.2 Chemical analysis of plant (Golden Rod)

3.2.1 Nitrogen (g $plant^{-1}$)- The uptake of nitrogen in golden rod plants was increased with increase in crop age. Significantly highest nitrogen uptake of 2.22 was recorded at mid stage in T_5 followed by T_4 (1.56) and T_3 (1.07). The lowest nitrogen uptake 0.24 was observed in T_7 followed by T_1 (0.40 g $plant^{-1}$) and T_2 (0.85 g $plant^{-1}$). The nitrogen uptake in T_2 and T_6 was on par with each other. The trend in nitrogen uptake at harvesting stage was similar to mid stage and it ranged from 0.28 in T_7 to 3.76 in T_5. In T_5 it was significantly more by 32.39% than T_4. The nitrogen uptake in T_2 was significantly more than T_1. Maximum nitrogen uptake in T_5 treated pot at mid and harvesting stages in Golden Rod was due to more availability of nitrogen and more soil organic carbon in soil as compared to rest of the treatments. Relatively high per cent of organic carbon in sewage sludge, increased the cation exchange capacity, which helped to retain essential plant nutrients within the rooting zone due to additional cation binding sites (Soon, 1981). Significantly higher N content in seeds of lentil grown with sewage sludge @ 1 to 6 kg m^{-2} was also reported by Yamur et al. (2005).

3.2.2 Phosphorus (g $plant^{-1}$)- The highest phosphorus uptake (1.70) at mid stage (45 DAT) recorded in T_5 was significantly superior as compared with rest of the treatments. Uptake ranged from 0.37 in T_7 to 1.36 in T_5. The increase in phosphorus uptake was more by 25.00% in T_5 than T_4. The trend observed in phosphorus uptake at harvesting stage (90 DAT) was similar to mid stage. Significantly highest uptake (3.01) and lowest uptake

(0.60) were obtained in treatments of T_5 and T_7, respectively. Increase in P content of corn (Bozkurt et al., 2000) and barley seeds (Naggar and Ghamry, 2001) grown in sewage sludge amended soil as compared to unamended soil was also reported.

3.2.3 Potassium (g plant^{-1})- The uptake of potassium increased as the crop age advanced. Maximum potassium uptake of 1.67 at mid stage (45 DAT) was recorded in T_5 followed by T_4 (1.23) and T_3 (0.83), which was unlike to nitrogen, phosphorus and potassium uptake that recorded in Golden Rod at mid stage. The increase in potassium uptake was more by 35.77% in T_5 than T_4. The lowest uptake of potassium (0.17) was recorded in T_7 followed by T_1 (0.31), similar to potassium uptake in Golden Rod. The trend observed in potassium uptake at 90 DAT was similar to 45 DAT. Significantly highest uptake of 3.16 and lowest uptake of 0.19 were obtained in treatments of 100% sewage sludge (T_5) and Control (T_7), respectively as compared with rest of the treatments. The highest potassium uptake in T_5 at mid and harvesting stages in Golden Rod as compared with rest of the treatments was due to more availability of potassium and soil organic carbon in the soil. Stark and Clapp (1980) showed that, crop yield and K uptake increased in potato with application of sewage sludge as compared with other treatments that did not receive sludge. Similar opinion was expressed by Soon (1981) and Singh and Agrawal (2010) which was mentioned in previous pages.

3.2.4 Zinc (mg plant^{-1})- The highest zinc uptake of 30.520 recorded at mid stage was observed in T_5 followed by T_4, similar to potassium uptake that noticed in same crop. The lowest zinc uptake (1.463) was observed in T_7 followed by T_1 (7.492) and RDF (8.783). The increase in zinc uptake was significantly more by 29.70% in T_5 than T_4. Zinc uptake at harvesting stage ranged from 2.876 in T_7 to 51.305 in T_5. In T_5, it was significantly more by 44.97% than T_4. The lowest zinc uptake (2.876) was recorded in T_7 followed by 20% sewage sludge treatment (16.784) and 40% sewage sludge treatment (22.053), similar to zinc uptake trend that recorded in Golden Rod. The Zn uptake was at adequacy level (Sailaja et al., 2011) in 80% and 100% sewage sludge treatments and it was deficient in rest of the treatments. Observation of maximum zinc uptake in T_5 treated pot at mid and harvesting stages in Golden Rod was due to more zinc availability in soil, favorable soil pH and presence of more soil organic carbon in the soil. This finding can be supported by the observations made by Singh and Agrawal (2008) that, macronutrients in the sewage sludge serve as a good source of plant nutrients and the organic constituents provide beneficial soil conditioning properties thus, due to more favourable conditions, the uptake of nutrients also would be more. Highest zinc concentration (22.07 mg kg^{-1}) was recorded in mung bean seeds at higher dose (12 kg m^{-2}) of sewage sludge application (Singh and Agrawal, 2010).

3.2.5 Heavy metals uptake

The HM was estimated in both plants and spikes of Golden Rod. The details are as follows.

3.2.5.1 Lead (Pb mg plant^{-1})- The observation of lead uptake in golden rod plant was increased as the crop age advanced. At 45 DAT, significant differences were observed among the treatments of sewage sludge and the highest Pb uptake of 7.665 was observed in T_5 followed by T_4 and T_3. The lowest Pb uptake of 0.213 was observed in T_7. The increase in uptake was recorded more by 44.60% in T_5 than T_4. The lead uptake recorded at harvesting stage ranged from 0.443 in T_7 to 7.998 in T_5. The lead uptake recorded in T_5 was significantly more by 44.63% than T_4. The Pb uptake in 60% sewage sludge treatment (4.062) was significantly more than (2.797), but the uptake recorded in 40% sewage sludge treatment (2.797) was on par with Recommended dose of fertilizer (1.480).

3.2.5.2 Lead (Pb mg spike^{-1})- The Pb uptake recorded in spikes at harvesting stage ranged from 0.128 in T_7 to 0.884 in T_5. The highest Pb uptake (0.884) was recorded in T_5 followed by 80% sewage sludge treatment (0.784) and 60% sewage sludge treatment (0.647). The increase in Pb uptake recorded in T_5 was significantly more by 12.76% than T_4, similar to trend of lead uptake that seen in spikes of Golden Rod. The trend of lead (Pb) uptake was beyond the maximum permissible limits in T_4 abd T_5 in plants as per the WHO standards and it was within the maximum permissible limits in rest of the treatments. In contrast, the uptake in spikes and spikes of both crops was within the maximum permissible limits in all treatments. More concentration and total lead (Pb) availability in T_5 as compared with rest of the treatments can be attributed to maximum lead uptake in spikes and plants of Golden Rod. The concentration of Pb was also reported by Akdeniz et al. (2006) in sorghum leaves (0.56, 0.49, 0.49 mg kg^{-1}) and seeds (0.44, 0.46, 0.45 mg kg^{-1}) when sewage sludge was used (@ 7, 14, 21 Mg ha^{-1}, respectively).

3.2.5.3 Nickel (Ni mg plant^{-1})- Ni uptake in golden rod plants was increased with the increase in crop age up to 90 DAT. Ni uptake of 2.859 at mid stage was highest in T_5 followed by 80% sewage sludge (2.496) and 60% sewage sludge (1.799). The lowest Ni uptake 0.198 was observed in T_7 followed by 20% sewage sludge (0.834) and 40% sewage sludge (1.331). The increase in Ni uptake was more by 14.54% in T_5 than T_4. Nickel (Ni) uptake at harvesting stage (90 DAT) ranged from 0.582 in T_7 to 3.012 in T_5. The Ni uptake recorded in 100% sewage sludge treatment (3.012), 80% sewage sludge treatment (2.623) and 60% sewage sludge treatment (2.183) was on par with each other. Similarly, 20% sewage sludge (1.218) and Control (0.582) were on par with each other, similar to Ni uptake that observed in Golden Rod at harvesting stage.

3.2.5.4 Nickel (mg spike^{-1})- The data recorded on Ni uptake in spikes ranged from 0.005 in T_7 to 0.701 in T_5. The Ni uptake recorded in T_5 was significantly more by 52.72% and 93.11% as compared with T_4 and T_3, respectively, similar to Ni uptake that noticed in Golden Rod spikes. The Ni uptake observed in 20% sewage sludge (0.059) was on par with Recommended dose of fertilizer (0.072 mg spike^{-1}). The nickel (Ni) uptake was within the maximum permissible limits in plants and spikes in all treatments as per the WHO standards (1996). Higher nickel (Ni) uptake in spikes and plants of Golden Rod in 100% sewage sludge treatment (T_5) and 80% sewage sludge treatment (T_4) was found to be due to more concentration and total Ni availability in these two treatments as compared with rest of the treatments.

3.2.5.5 Cobalt (Co mg plant^{-1})- The uptake of cobalt in golden rod plants was linearly increased with advancement in crop age. The data on cobalt uptake at 45 DAT recorded in T_5, was significantly different as compared with other treatments. The Co uptake ranged from 0.099 in T_7 to 1.989 in T_5. The increase in cobalt uptake was more by 10.75% in T_5 than T_4, unlike to Co uptake trend that recorded in Golden Rod at mid stage. The trend observed in cobalt uptake at harvesting stage (90 DAT) was similar to mid stage (45 DAT). Significantly highest 2.279 and lowest cobalt uptake 0.199 were obtained in treatments of 100% sewage sludge (T_5) and Control (T_7), respectively.

3.2.5.6 Golden (Co mg spike^{-1})- Cobalt uptake in spikes ranged from 0.012 in T_7 to 0.526 in. The maximum Co uptake (0.526) was noticed in T_5 which was significantly more by 69.68% than T_4. The uptake recorded in 20% sewage sludge (0.056), 40% sewage sludge (0.073) and Recommended dose of fertilizer (0.061) was on par with each other, similar to Co uptake trend that noticed in Golden Rod spikes. The cobalt (Co) uptake was beyond the maximum permissible limits in 80% sewage sludge and 100% sewage sludge treatments in plants and it was

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within the maximum permissible limits in rest of the treatments. But, uptake in spikes was within the maximum permissible limits in all treatments (WHO standards, 1996). The higher uptake of cobalt (Co) was recorded in T_5 in spikes and plants of Golden Rod can be attributed to more concentration and total Co availability in T_5. Similar result was also expressed by Saruhan et al. (2010) in Lotus corniculatus that, the concentration of cobalt (Co) in plant increased (0.42, 0.56 and 0.63 mg kg^{-1}, respectively) with the increase in sewage sludge application rates (@ 3, 6 and 9 t ha^{-1}).

3.2.5.7 Cadmium (Cd mg $plant^{-1}$)- Signifi-cantly highest Cd uptake of 0.176 at mid stage was observed in T_5 followed by T_4 (0.084) and 60% sewage sludge (0.067). The lowest Cd uptake of 0.001 was observed in T_7 followed by 20% sewage sludge treatment (0.014). The uptake recorded in T_1 (0.014), T_2 (0.036) and T_6 (0.019) was on par with each other. Cadmium uptake at harvesting stage ranged from 0.002 in T_7 to 0.275 in T_5. In T_5 it was significantly more by 90.97% than T_4. The Cd uptake in 40% sewage sludge treatment (0.056) was also significantly more than 20% sewage sludge treatment (0.024).

3.2.5.8 Cadmium (Cd mg $spike^{-1}$)- The maxi-mum Cd uptake (0.218) was noticed in T_5 followed by 80% sewage sludge treatment (0.120) and 60% sewage sludge treatment (0.069). The increase in Cd uptake was significantly more by 81.67% in T_5 than T_4. The lowest cadmium uptake (0.002) was recorded in T_7 followed by 20% sewage sludge (0.017) and 40% sewage sludge treatment (0.048). The trend of Cd uptake was beyond the maximum permissible limits only in 100% sewage sludge treatments in plants uptake was within the maximum permissible limits in spikes in all the treatments as per the WHO standards. Observation of maximum cadmium (Cd) uptake in T_5 treated spikes and plants of Golden Rod were due to more concentration and total Cd availability in T_5 as compared with rest of the treatments. This finding can be corroborated by the observation made by Akdeniz et al. (2006) that, the concentration of Cd was increased linearly in sorghum leaves (0.56, 0.49, 0.49 mg kg^{-1}) and seeds (0.44, 0.46, 0.45 mg kg^{-1}) when sewage sludge (@ 7, 14, 21 Mg ha^{-1}, respectively) application rate increases linearly.

IV. SUMMARY AND CONCLUSIONS

Major nutrients uptake *viz*., NPK by plants of Golden Rod was linearly increased with increase in sewage sludge application rates. Significantly highest and lowest uptake of these nutrients was noticed, respectively in treatment of 100% sewage sludge application and Control (T_7) at both sampling stages. Significantly highest Zn uptake by plants of Golden Rod at mid and harvesting stages was recorded by the T_5. The lowest uptake of Zn recorded by the T_7 which was on par with T_1 at both stages. The maximum uptake of Zn in plants was at adequacy level.

Uptake of heavy metals (Pb, Ni, Co and Cd)- The heavy metals were estimated in both plants and spikes at mid and harvesting stages. The effect of sewage sludge on the uptake of heavy metals *viz*., Pb, Ni, Co and Cd was significantly highest in treatment of T_5. The Pb and Co uptake was beyond the maximum permissible limits (WHO, 1996) in 80% sewage sludge and 100% sewage sludge in plants. But, the cadmium uptake was beyond the maximum permissible limits (WHO, 1996) in 100% sewage sludge in plants. In contrast, the uptake of Ni by plants was within the maximum permissible limits (WHO, 1996) in all treatments. Uptake of heavy metals *viz*., Pb, Ni, Co and Cd in spikes was within the maximum permissible limits in all treatments as per the WHO standards (WHO, 1996).

V. CONCLUSIONS

The NPK content of sewage sludge used in the present experiments was high along with organic carbon content. The content of heavy metals Pb, Ni, Co and Cd was within maximum permissible limits. Highest uptake of major nutrients (NPK), micronutrient (Zn) and heavy metal like Ni were within maximum permissible limits either in spikes and plants of Golden Rod in 100% sewage sludge treatment (T_5). Uptake of heavy metals *viz*., Pb, Ni, Co and Cd in spikes and plante were within the maximum permissible limits as per WHO standards (WHO, 1996).

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