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Organic Soil Amendments: Potential Source for Heavy Metal Accumulation

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ABSTRACT

Effects of heavy metals on plants result in growth inhibition, structure damage, a decline of physiological and biochemical activities as well as of the function of plants. The effects and bioavailability of heavy metals depend on many factors, such as environmental conditions, pH, and species of element, organic substances of the media and fertilization, plant species. But, there are also studies on plant resistance mechanisms to protect plants against the toxic effects of heavy metals. The microorganisms act in synergism with the plants for effective phytoremediation. This synergistic relationship promotes the exchange of water and nutrients established between plant roots and specialized soil microorganisms thus, enhancing the plant growth. The application of microorganisms in phytoremediation helps to improve plant growth and survival rate. The microbial activity in the contaminated site acts as an indicator for the plant growth and bioremediation. So an attempt were made on the toxic effects of chromium in paddy plants growth and yield and thereby mitigating its toxicity by using microbial inoculants especially *Azospirillum.*

Keywords**:** Heavy metals; Bioremediation; Biofertilizers; Growth; Yield

1. INTRODUCTION

Soil and water are precious natural resources on which rely the sustainability of agriculture and the civilization of mankind. Unfortunately, they have been subjected to maximum exploitation and severely degraded or polluted due to anthropogenic activities. The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, and nonpoint sources such as soluble salts (natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizers (McGrath et al., 2001; Nriagu and Pacyna, 1988; Schalscha and Ahumada, 1998; Garbisu and Alkorta, 2001). Each source of contamination has its own damaging effects to plants, animals and ultimately to human health, but those that add heavy metals to soils and waters are of serious concern due to their persistence in the environment and carcinogenicity to human beings. In order to maintain good quality of soils and waters and keep them free from contamination, continuous efforts have been made to develop technologies that are easy to use, sustainable and economically feasible.

Heavy metals are one of the most important groups of pollutants of aquatic environment and it is considered to be a serious environmental problem facing the modern world (Dushenkov *et al.*, 1995). Addition of heavy metals likes As, Cu, Cd, Pb, Cr, Ni, Hg and Zn etc., into the environment and their subsequent toxic and carcinogenic effects on flora and fauna cause a great ecological crisis at global level (Sankar ganesh, 2009). The sources of various heavy metals are listed in Table 1. The presence of any metal may vary from site to site, depending upon the source of individual pollutant. Excessive uptake of metals by plants may produce toxicity in human nutrition, and cause acute and chronic diseases. High concentrations of heavy metals in soil can negatively affect crop growth, as these metals interfere with metabolic functions in plants, including physiological and biochemical processes, inhibition of photosynthesis, and respiration and degeneration of main cell organelles, even leading to death of plants (Garbisu and Alkorta, 2001; Schwartz et al., 2003). Soil contamination with heavy metals may also cause changes in the composition of soil microbial community, adversely affecting soil characteristics (Kozdroj and van Elsas, 2001; Kurek and Bollag, 2004).

Table 1. Different sources of heavy metals.

Heavy metals	Sources	Reference
Arsenic	Semiconductors, petroleum refining, wood preservatives, coal power plants, herbicides, volcanoes, mining and smelting.	(Nriagu, 1994; Walsh et al., 1979)
Copper	Electroplating industry, smelting and refining, mining, biosolids.	(Liu et al., 2005)
Cadmium	Geogenic sources anthropogenic activities, metal smelting and refining, fossil fuel burning, application of phosphate fertilizers, sewage sludge	(Nriagu and Pacyna, 1988), (Alloway, 1995; Kabata-Pendias, 2001)

Chromium	Electroplating industry, sludge, solid waste, tanneries.	(Sankar ganesh *et al*, 2009)
Lead	Mining and smelting of metalliferous ores, burning of leaded gasoline, municipal sewage, and industrial wastes enriched in Pb, paints.	(Gisbert et al., 2003; Seaward and Richardson, 1990).
Mercury	Volcanic eruptions, forest fire, emissions from industries producing caustic soda, coal, peat and wood burning	(Lindqvist, 1991)
Selenium	Coal mining, oil refining, glass manufacturing industry, chemical synthesis i.e., varnish, pigment formulation.	(Saffaryazdi., et al., 2012)
Nickel	Volcanic eruptions, bubble bursting and gas exchange in ocean, weathering of soils and geological materials	(Knox et al., 1999)
Zinc	Electroplating industry, smelting and refining, mining, biosolids	(Liu et al., 2005)

Biological approaches of remediation include: (1) use of microorganisms to detoxify the metals by valence transformation, extracellular chemical precipitation, or volatilization [some microorganism can enzymatically reduce a variety of metals in metabolic processes that are not related to metal assimilation], and (2) use of special type of plants to decontaminate soil or water by inactivating metals in the rhizosphere or translocating them in the aerial parts. This approach is called phytoremediation, which is considered as a new and highly promising technology for the reclamation of polluted sites and cheaper than physicochemical approaches (Garbisu and Alkorta, 2001; Raskin et al., 1997).

There are different categories of phytoremediation, including phytoextraction, phytofiltration, phytostabilization, phytovolatization and phytodegradation, depending on the mechanisms of remediation. Phytoextraction involves the use of plants to remove contaminants from soil. The metal ion accumulated in the aerial parts that can be removed to dispose or burnt to recover metals. Phytofiltration involves the plant roots or seedling for removal of metals from aqueous wastes. In phytostabilization, the plant roots absorb the pollutants from the soil and keep them in the rhizosphere, rendering them harmless by preventing them from leaching. Phytovolatization involves the use of plants to volatilize pollutants from their foliage such as Se and Hg. Phytodegradation means the use of plants and associated microorganisms to degrade organic pollutants (Garbisu and Alkorta, 2001).

In recent years, Biofertilizers have emerged as a promising component of integrating nutrient supply system in agriculture. Our whole system of agriculture depends in many important ways, on microbial activities and there appears to be a tremendous potential for making use of microorganisms in increasing crop production. Microbial fertilizers are an important part of environment friendly sustainable agricultural practices (Bloemberg et al., 2000). The soil bacterium *Azospirillum* was first isolated and originally named as *Spirillum lipoferum*. This bacterium was later isolated from soil and from dried seaweed in Indonesia and as a phyllosphere bacterium in tropical plants (Becking, 1985). Reclamation of wasteland is very essential to avoid the environmental deterioration. To alleviate the harmful effect of chromium polluted soil, various types of soil amendments were used to restore the fertility of chromium-polluted soil. The productivity of crops grown in general is very much affected due to irrigation with chromium-contaminated water. To manage the soils already polluted with chromium water irrigation, many soil amendments such as composted coir pith, farmyard manure, vermicompost, gypsum and *Azospirillum* were employed.

2. MATERIALS AND METHODS

A Field experiment was conducted with paddy crop grown in (1 metre × 1 metre plots) chromium polluted soil mixed with some soil amendments such as composted coir pith, vermicompost, farmyard manure, *Azospirillum* and gypsum. The soil amendments were given as follows:

T_0 – Control
T_1 – Polluted soil + Composted coir pith (0.50 kg/plot)
T_2 – Polluted soil + Vermicompost (0.50 kg/plot)
T_3 – Polluted soil + Farmyard manure (1 kg/plot).
T_4 – Polluted soil + *Azospirillum* (0.25 kg/plot)
T_5 – Polluted soil + Gypsum (0.50 kg/plot)
T_6 – Polluted soil

The seeds of paddy (variety ASD 16) was sown in this field and irrigated with well water three times in a week. Three replicates were maintained for this experiment. Five plant samples were randomly selected and they were used for recording the morphological parameters

2. 1. Root length and shoot length

The root length and shoot length of plant samples were measured by using centimeter scale and recorded

2. 2. Total leaf area (Kalra and Dhiman, 1977)

The plant samples were collected periodically and the length and breadth of the leaf samples were measured and recorded. The total leaf area was calculated by using the Kemp's constant.

$$\text{Total leaf area} = L \times B \times \text{Kemp's constant (for Monocot-0.9)}$$

2. 3. Fresh and dry matter production

The same plant samples were taken for morphological studies were also used for the determination of fresh weight by using electrical single pan balance. Their dry weights were determined by keeping the plant materials in a hot air oven at 80 °C for 24 hrs and recorded.

2. 4. Yield and yield components

Five plants were selected randomly from each plot. Number of panicles, panicle length, number of grains, 1000 grain weight and their yield components were measured.

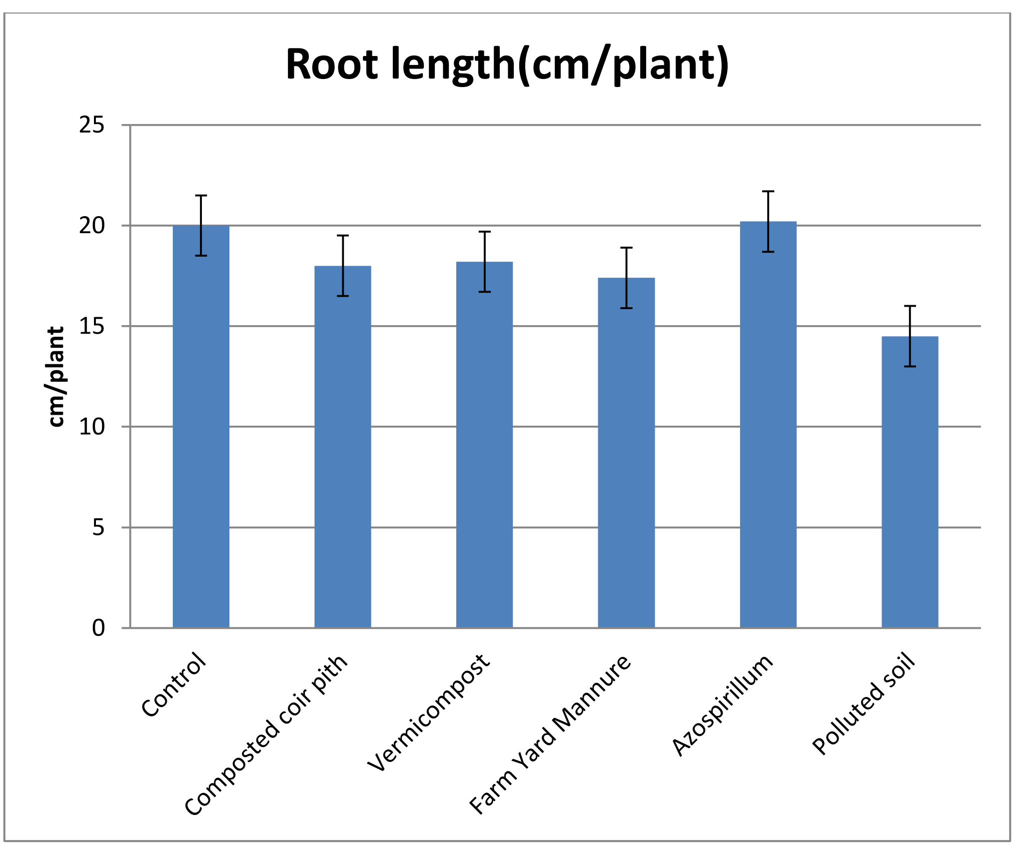
3. RESULTS AND DISCUSSION

Field experiment was conducted with paddy variety (ASD 16) in chromium polluted soil mixed with various soil amendments. Among the soil amendments, the soil mixed with *Azospirillum* performed better. The highest morphological and yield parameters of paddy were recorded in the polluted soil mixed with *Azospirillum* application. The order of growth and yield performance were reported in the crop grown in the polluted soil mixed with *Azospirillum* > composted coir pith > farmyard manure > vermicompost > gypsum. Thangavel (2004) reported the increase in growth and yield of maize crop grown in chromium polluted soil mixed with various soil amendments. The higher growth and yield performance of paddy crop were recorded in the soil mixed with *Azospirillum* followed by composted coir pith. Biofertilizers are cost effective, eco-friendly, renewable source of plant nutrient to supplement chemical fertilizers (Kannaiyan, 2002). Nitrogen is one of the major important nutrients very essential for crop growth. *Azospirillum* one of the biofertilizers not only fixes nitrogen but also benefit plants by supplying growth hormones and vitamins (Saini *et al.*, 2004). The *Azospirillum* inoculation improved water status in stressed plants. Bacterial inoculation caused increases the root length, root elongation zone, number and length of lateral roots, increase in dry weight, number and density and early appearance of root hairs, enhanced cell division in the meristem. Further, it helps to survive under stress conditions by limiting the toxicity level in the medium and by increasing the Auxin content in the plants (Bashan and Levanony, 1990). Plant Growth Promoting Rhizobacteria (PGPR) has the ability to increase plant growth and the yield of crops (Bashan, 1991; Saleem *et al.*, 1994). Growth stimulation and fresh weight of *Triticum aestivum* seedlings were reported under chromium stress by non-rhizospheric *Pseudomonas* strains. The linear reduction in fresh weight of seedlings in different treatments with $CrCl_3$ and K_2CrO_4 were recorded when compared to non-inoculated treatments (Hasnain and Sabri, 1997). But the symptoms of chromium toxicity were also reversed and root development was improved with bacterial inoculations.

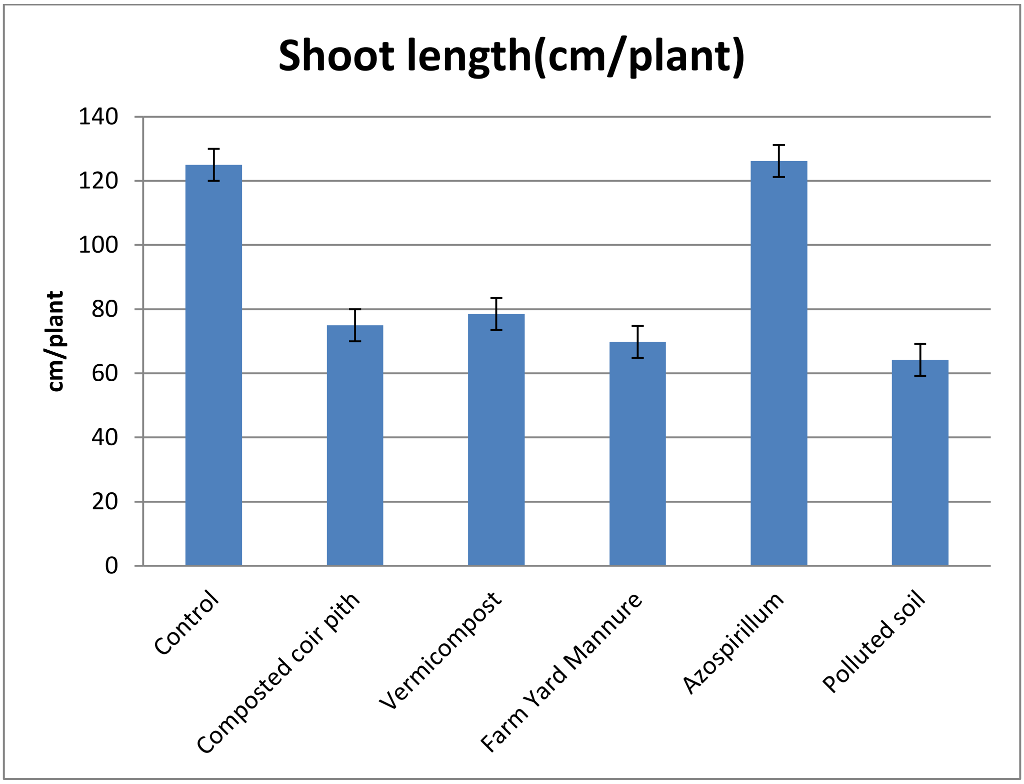
The application of organic amendments resulted in Cr(VI) reduction either from an enhancement of the microbial population and microbial activity. In addition it enhanced the abiotic process of Cr (VI) reduction by supplying organic carbon (Losi *et al.*, 1994). The addition of organic amendments such as biosolid compost, farmyard manure, fish manure, horse manure, pig manure and poultry manure were involved to reduce hexavalent chromium in a mineral soil low in organic matter. Organic manures increased the plant growth and yield as well as the soil quality. The fertility of soil will be increased by decomposition of organic matter through microbial population and their activities (Ravichandran and Rajan, 2005). Coir waste could be a viable substitute in replacing the scarcity of farmyard manure in terms of its nutrient value and amending nature by producing better physical and chemical properties of soil. The application of coir pith kept the soil moist prevented the capillary rise of salts from sub surface layers and greater leaching of the salts from the root zone. When the salt load in the root zone is reduced, the establishment of the crop is good which resulted in enhanced productivity (Perumal and Singaram, 1996; Singaram, 1995).

Application of gypsum and FYM improved the physical condition of the soil, better availability of water and nutrients to the plant (Sharma *et al.*, 2003; Singh and Singh, 2005). Addition of compost or manure together with lime to raise soil pH is a common practice for immobilization of heavy metals and soil amelioration, to facilitate re-vegetation of contaminated soils (Clemente *et al*., 2003). There was a significant difference in the extent of Cr(VI) reduction among the soils treated with organic amendments (Bolan and Thiyagarajan, 2001; Bolan *et al.*, 2003). The application of lime ($CaCO_3$) and fertilizer increased the growth performance and oil content of *Palmarosa* grown under heavy metal contaminated soil (Behura and Pradhan, 2001). This was due to the application of lime that had reduced the adverse effect of heavy metals and created better soil environment for the growth of *Palmorosa*. This is in accordance with the results of Mascarenhas *et al.* (1976) and Finogenova (1977).

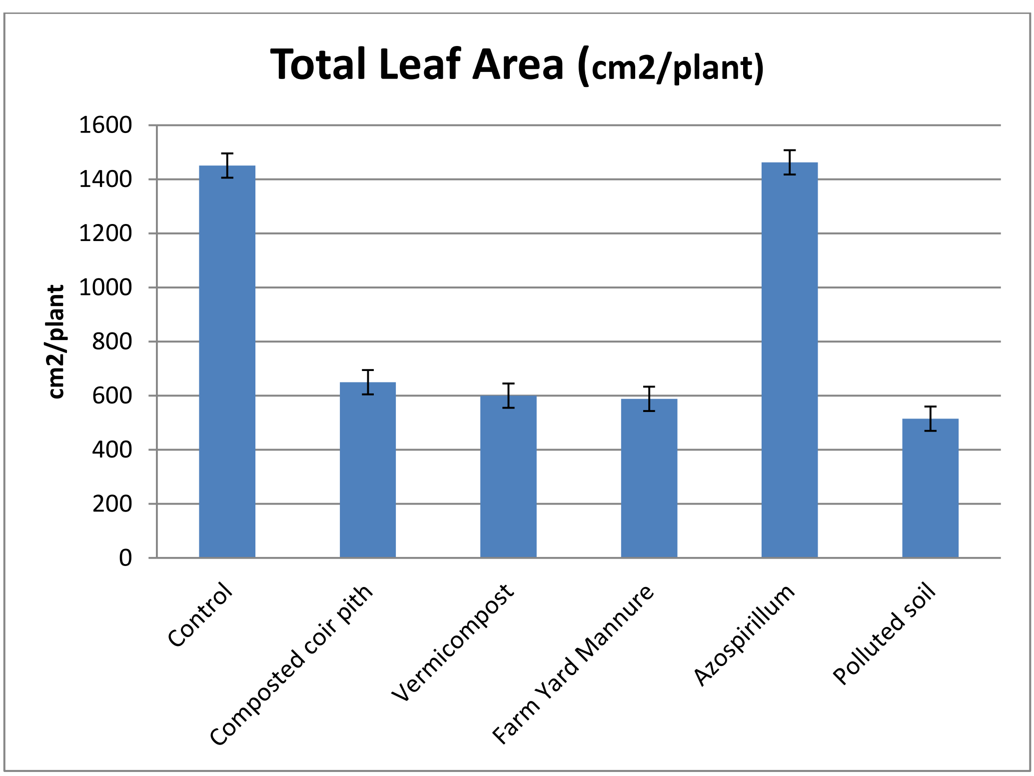
The effects of organic amendments on heavy metal bioavailability depend on the nature of the organic matter, their microbial degradability, salt content and effects on soil pH and redox potential, as well as on the particular soil type and metals concerned (Walker *et al.*, 2003; 2004). The effects of FYM when applied with higher rate of heavy metals thereby resulting in higher dry matter yield. Interaction of organic manure with heavy metals causes the changes in soil pH which determine immobilization or mobilization of metals. The environment around the completing site will affect metal complexation by soil organic matter, particularly pH and the metal species taking part in the process (Ross, 1994).



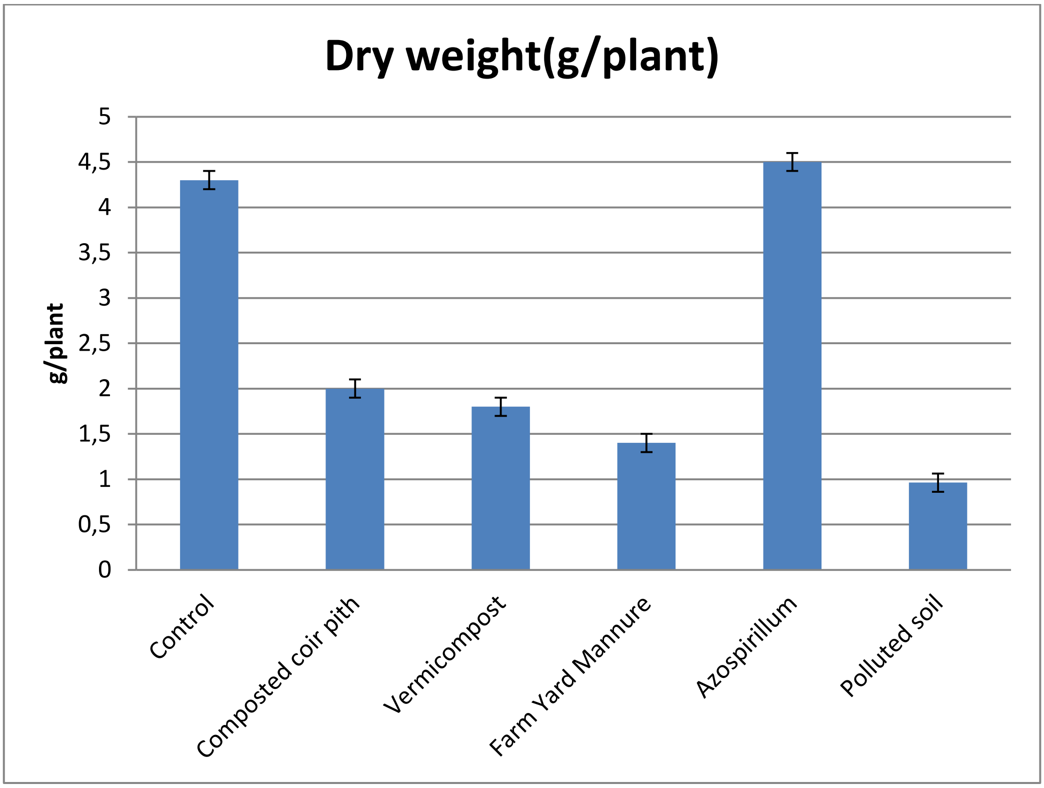
(A)


Shoot length(cm/plant)
cm/plant
140
120
100
80
60
40
20
0
Control
Composted coir pith
Vermicompost
Farm Yard Mannure
Azospirillum
Polluted soil

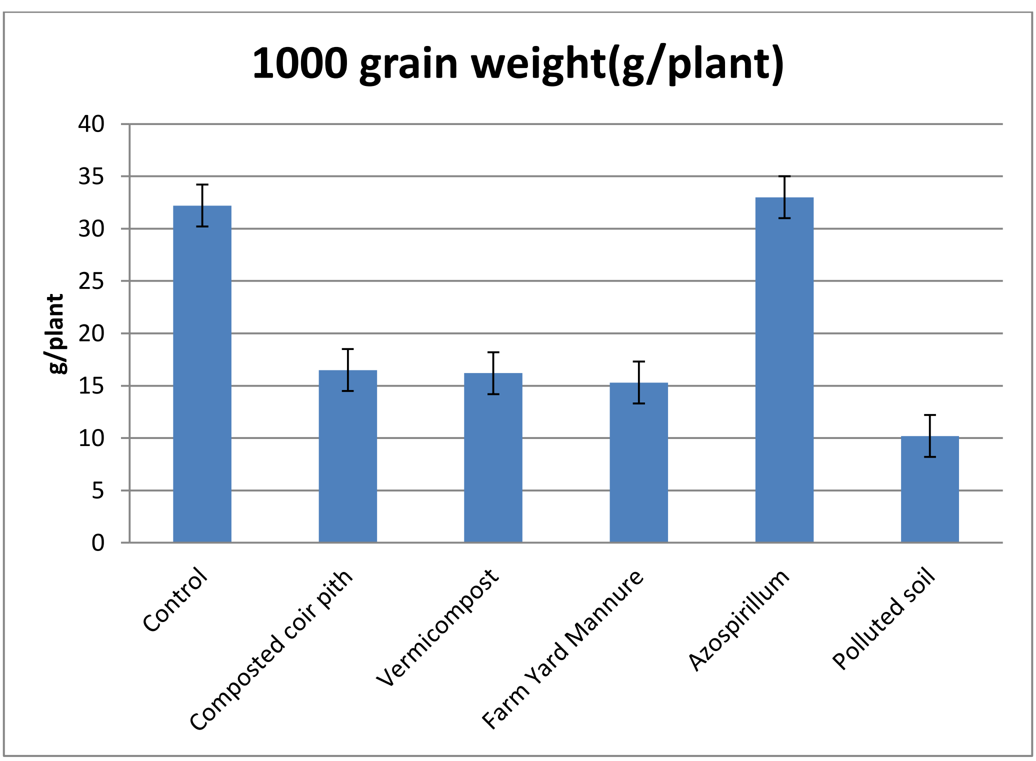
(B)


Total Leaf Area (cm2/plant)
cm2/plant
1600
1400
1200
1000
800
600
400
200
0
Control
Composted coir pith
Vermicompost
Farm Yard Mannure
Azospirillum
Polluted soil

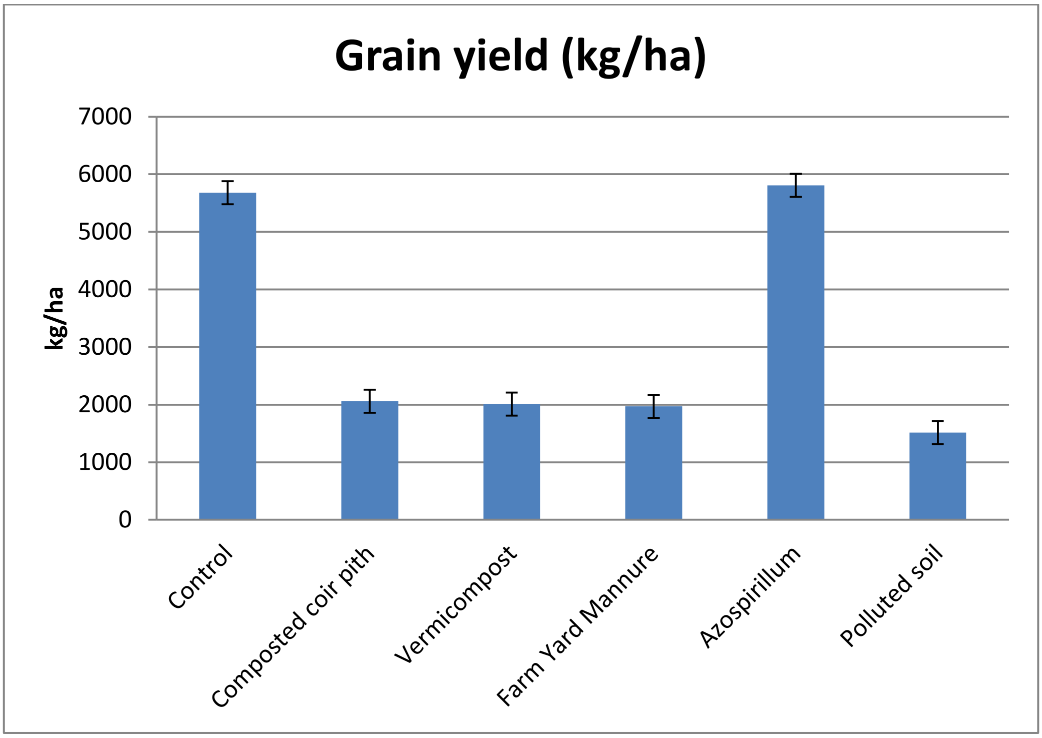
(C)


Dry weight(g/plant)
g/plant
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
Control
Composted coir pith
Vermicompost
Farm Yard Mannure
Azospirillum
Polluted soil

(D)


1000 grain weight(g/plant)
g/plant
40
35
30
25
20
15
10
5
0
Control
Composted coir pith
Vermicompost
Farm Yard Mannure
Azospirillum
Polluted soil

(E)



(F)

Fig. 1(A-F). Effect of application of various soil amendments on growth and yield parameters of paddy (*Oryza sativa* L. var. ASD 16) grown under chromium polluted soil.

4. CONCLUSION

It may be concluded that mitigation of polluted soil by using microbial inoculants reduce the toxicity of heavy metals as well as increase the growth of plants by supplying growth promoting hormones.

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