Journal of
Plant Science & Research

Volume 10, Issue 1 - 2023

www.opensciencepublications.com

Evaluation of heavy metal content in soil, and *Brassica comprestis* crop in the farms of Parasamaniya Platue of Madhya Pradesh

Research Article

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Article Information: Submission: 27/01/2023; **Accepted:** 24/02/2023; **Published:** 28/02/2023

Abstract

Phytoremediation involves the use of plants to remove contaminants in situ from various natural resources such as soil, silt, sediment, and groundwater. Phytoremediation offers promising prospects for the removal of various pollutants from soil as it offers many benefits and removes pollutants from soil without affecting soil properties. In this context, it was also of interest for farmers to know which local plant varieties of Parasamaniya Platue have the potential for Phytoremediation. As *Brassica comprestis* is of interest to farmers, there is still no scientific knowledge on the balance between crop efficacy and soil properties for the local varieties of Parasamaniya Platue. Therefore, it is important to evaluate soil quality and its effects on the physiology of crop varieties grown in the area. In addition, the field soils and selected *Brassica comprestis* crops have different metal contents such as K, Cu, Fe, Mn, Cd, Pb, and Zn, suggesting that *Brassica comprestis* (mustard), a regional crop, has the potential to remediate heavy metal ions.

Keywords: *Brassica comprestis*; Heavy metal; Phytoremediation; Soil analysis

Introduction

Rising level of heavy metal is primary concern in the modern towns and nearby areas. Due to increased mining, heavy construction sites, dense and busy transport system, paint industries and cement factories the amount of fly ash and waste rich in heavy metal is continuously being added in the ecosystem and therefore its reported levels are tremendously high, There are several studies which report increased amount of heavy metal contaminant in soil, air and water in Vindhya region including Parasamaniya plateau in recent years. This contamination poses a risk to environmental and human health. Some heavy metals are carcinogenic, mutagenic, teratogenic and endocrine disruptors while others cause neurological and behavioural changes especially in children. Flora and fauna of the regions is under severe stress and burden of these heavy metals. Consequently the yield of cultivated crop varieties are challenged which in turn brought the farmer's life at risk [1-5].

Since the industrialization has begun, the extensive mining and processing of heavy metals by man has led to the release of these elements into the environment. Since heavy metals are non biodegradable, they gradually accumulate in the environment and subsequently contaminate the food chain [6]. This contamination poses a risk to environmental and human health. Some heavy metals are carcinogenic, mutagenic, teratogenic and endocrine disruptors while others cause neurological and behavioural changes especially in children. The majority of metals occur naturally in soil and at varying bio-availabilities. According to, metals can be categorized as readily bio-available (Cd, Ni, Zn, As, Se, Cu), moderately bio-available (Co, Mn, Fe) and least bio-available like Pb, Cr and U [7].

ISSN: 2349-2805

Phytoremediation can be one of excellent opportunity to reduce the level of heavy metal from natural resource and ecosystem. This is one of the ways of bioremediation. The term "bioremediation" has been introduced to describe the process of using biological agent to remove toxic waste from the environment. The remedy provided by a plant to its ecosphere is known as Phytoremediation. Phytoremediation uses plants for in-situ removal of contaminants from various natural resources like soils, sludge, sediments and ground water [8]. Phytoremediation has promising prospects for the removal of different contaminants from soil because of its several advantages. For instances it is usually carried out in-situ without risking humans or environment, and contaminants are removed from soil without affecting soil properties, allowing for reuse of soil [9,10].

Generally most plants offer a sustainable source of restoration to its ecosystem. However every plant species differs in its ability to perform a physiological adaptation, tolerance and remedial ability when grown in contaminated land and water. Here our interest was to know which crop varieties are having Phytoremediation potential with the farmer's interest too and we found that *Brassica comprestis* crop plant is of interest and therefore can be easily utilized without significant changes in farmer's interest. A scientific understanding of balance between plant abilities and soil properties is not done yet for the local cultivars of Parasamaniya plateau. Therefore it is important to assess the quality of soil and its effect in physiology of locally cultivated varieties of crops. From the futuristic point of view, we need potential candidate of Phytoremediation abilities that can grow for green solution with agriculture benefits. Here in the present study, we investigated the different soil parameters like pH, electric conductivity (EC), Organic carbon content, Nitrogen and phosphorus. We have also investigated the different metal content e.g. K, Cu, Fe, Mn, Cd, Pb and Zn in the field soil and selected crop plant of *Brassica comprestis* and possibility of remediation of heavy metal ions by local crop of *Brassica comprestis* (Mustard) in Parasamaniya Platue.

Materials & Methods

Soil and Plant Sample Collection

Soil Sample was collected from field of Parasamaniya plateau in the Satna district of Madhya Pradesh spread in geographical area of 782.69 hectare. This Platue is resided in the Vindhya mountain chain. Crop field was visited and soil from the morphologically well grown matured plant of the *Brassica comprestis* farm was collected in the last week of January month. Selected plant and soil were collected from central and peripheral region of the region. Site of sample collection was properly recorded. We have also collected some soil of nearby area which is not being used in farming for comparison.

Preparation of soil samples for Analysis of different soil parameters

Scoop up soil into a clean, dry plastic bag. Remove stones and crush any clumps of soil for better results. Seal each sample after weighing to avoid moisture loss. No sample preparation or preservative required. Routine testing for pH, electric conductivity (EC), nitrogen, phosphorous, and organic matter is designed to handle the analyses in series of groups of 3. The soil samples, at the time they are received, are recorded and placed in trays holding five rows of three boxes each (boxes are 2.5" x 3" x 3" deep), making a total of 15 samples. Each tray is lettered or numbered and sample identification follows each set of numbered racks through the entire analysis.

For pH 15g of field soil was taken into 3 replicate in 100ml beaker. Using a graduated cylinder 30 ml deionized water is added to each beaker, sealed and shaken for a few seconds. The seal is removed to allow the solution to equilibrate with the atmosphere for at least 30 minutes. The pH meter is standardized at pH 7 and 4.While gently swirling the slurry the electrode is placed into the slurry. pH is measured to the nearest 0.01. Between samples the electrode is rinsed with deionized water.

For soil EC, rinsed a container with deionized water and allowed to completely dry. Take the soil sample in container and make thick slurry by mixing deionized water. Pass the samples the sample through a filter over a funnel. After filtration pour some of the filtered sample into a clean beaker to rinse it. Afterwards, discard the sample used for rinsing. Fill the beaker with enough extracted water to submerge the probe. Rinse the probe with deionized water, and then a little bit of the sample. Take the EC measurement in triplicate. The EC results were the average of 3 different measurements.

For Organic carbon content estimation of soil was performed by using Walkley & Black chromic acid wet oxidation method. Total Nitrogen in the soil was estimated by the Kjeldahl method (Bremner 1960). Total available Phosphorus is determined by using Bray no1 extract method [4].

Analysis of soil Metal content: The soil available metal was extracted by 0.005M DPTA (Diethylene Triamine Penta Acetic acid pH 7.3) 0.01N Calcium Chloride and 0.1M triehanolamine (TEA) [11,12]. All the samples were filtered and readings were taken by ICP-Mass spectroscopy (QQQ) at department of soil science, Jawaharlal Nehru Agriculture University Jabalpur MP.

Plant sample preparation and analysis of Plant Metal content: 0.5 gram of each plant samples were in digestion vessels followed by addition of acid into vessels (trace metal grade JT Baker). Samples were digested in Microwave oven at 2400C for 50 minutes. Then samples were filtered and readings were taken by ICP-Mass spectroscopy (QQQ). All the results are average of three individual experiments and blank values were subtracted during analysis process.

Results & Discussion

Analysis of soil parameters in Parasamaniya Platue

The soil parameters studied are pH, Electrical conductivity (mmhos/cm), organic carbon in %, available Nitrogen (in kg/ha), and available Phosphorous (in kg/ha). Effects of these parameters in soil of Parasamaniya Platue are analyzed and the values are presented in Table 1.

pH: Soil pH is a measure of the hydrogen ion activity in soil solution. This measure is generally considered an index of the acid or base intensity of a soil [13]. Soil acidity has a direct effect on the

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Table 1: Different soil parameters e.g., pH, EC, organic carbon content, Nitrogen and Phosphorus in Collected soil samples of Parasamaniya Platue of Vindhya region of Madhya Pradesh.

Soil type	PH	Electric conductivity (mmhos/cm)	Organic carbon (in%)	Nitrogen kg/ha.	Phosphorus P_2O_5 (kg/ha.)
Field surface soil	7.21	0.45	0.51	178.00	34.13
Field underground soil	7.19	0.31	0.48	218.78	42.47
Nearby land soil	7.11	0.27	0.53	225.19	41.34
Average	**7.17**	**0.34**	**0.50**	**207.32**	**39.31**

plant and is a major factor affecting nutrient availability to plants. pH of surface soil, Ground soil and nearby land varies from 7.11 to 7.21 i.e. pH is neutral and normal condition under prescribed normal limit of (6.5 to 7.5) for soil health parameters. It indicates that in the Parasamaniya region the average value of soil pH does not change very significantly.

Electrical conductivity (mmhos/cm): Saturation Extract EC is the traditional method is the measurement of salt amount in soil which can be converted to soil salinity [14]. The electric conductivity parameters prescribed for Rewa division by State Agricultural department of Madhya Pradesh are as follows:

EC < 1.0 Normal

1 < EC < 2.0 Prohibited

EC > 2.0 dangerous

Average Electrical conductivity for soil of Parasamaniya range is 0.34. This varies from 0.27 to 0.45 for various taken soil samples. In our Results we find that surface soil of Brassica field have more EC (0.45) in comparison with field underground soil (0.31) and Nearby land soil (0.27) which indicate the electrical conductivity of does not vary significantly but it remains 0.31 to 0.27 for field underground soil and nearby land soil and overall maintains its normal average value of 0.34 for all soil samples taken from field.

Organic carbon content (in %): Soil organic matter is a primary indicator of soil quality. Improvements in soil organic matter create a more favorable soil environment, leading to increases in plant growth [11]. The organic carbon (in %) prescribed for good soil by state Agricultural department of Madhya Pradesh for Rewa division is as follows :

Low organic matter – if OC < 0.5,

Medium - if 05 < OC < 0.75,

High - if OC > 0.75

The observed values of organic matter content in percentage for various taken soil samples are 0.51, 0.48, and 0.53 for field surface soil, field underground soil and nearby land soil respectively which is almost near to low categories. This indicates that observed value of organic matter is low in field underground soil, while OC content in surface and nearby land soil lies in between medium range.

Available Nitrogen (in kg/ha):

Nitrogen is the major element of any soil for crop productivity [9]. Depending of available nitrogen in kg/ha the state agricultural department of Madhya Pradesh for Rewa division classified as:

Low availability- if N2 kg/ha < 250 kg/ha,

Medium availability- if N2 in kg/ ha, is between 250 to 400 kg/ha,

High availability – if N2 in kg/ha > 400 kg/ha.

Results for Nitrogen availability for whole forest of Parasamaniya range indicate that there is low availability of Nitrogen in whole region with mean values of available Nitrogen is 207.32 kg/ha. The observed value of available nitrogen in field underground soil (218.78 kg/ha) and nearby land soils (225.19 kg/ha) are very close to mean value of 207.32 kg/ha but it decreases very significantly in field surface soil (178 kg/ha). The observed value indicates we need to add nitrogen fertilizers to improve in available nitrogen in fields of Parasamaniya region for better yield of crops.

Available Phosphorous in terms of P2O5 (in kg/ha):

It is the major essential element of soil for proper plant growth and development and analyze in the term of kg/ha. The Madhya Pradesh State agriculture department of Rewa division presents his limit value of available phosphorous for health of soil which is:

If P2O5 < 23 kg/ha, low availability,

If P2O5 is between (23-46 kg/ha), medium availability,

If P2O5 > 46 kg/ha, high availability.

The results of available phosphorous in kg/ha for whole Parasamaniya range indicates that it is 39.31kg/ha which lies in medium category. Thus availability phosphorous in kg/ha is medium in whole area. This may be due to soil and rock formation of area and it depends on topography, and geology of the area. Further addition of phosphorous fertilizers should be avoided as a management strategy.

Analysis of heavy metals in Soil

The Heavy metal content present in the soil of Parasamaniya Platue are analyzed and presented in Table 2.

Zinc (in ppm): It is An Indispensable Micronutrient of soil for plant development and measured in part per million (ppm) [15]. The Madhya Pradesh State Agriculture department of Rewa division presented the sufficiently of zinc element for the fertility of soil and it is as follows:

if available Zinc < 0.5 ppm deficient,

if available Zinc > 0.5 ppm sufficient.

Table 2: The Heavy metal content present in the soil of Parasamaniya Platue.

Soil Type	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Cd (ppm)	Pb (ppm)	K (ppm)
Field Surface soil	1.76	64.54	10.45	1.22	0.02	0.641	76.74
Field underground soil	34.56	11292	249.49	1.35	0.084	11.27	4180
Average	**18.16**	**5678.27**	**129.97**	**1.285**	**0.52**	**5.95**	**2128.37**

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The results of available Zn for soil of Parasamaniya region indicates, the average value of zinc is 18.16 ppm, which shows that soil of whole range is over efficient in Zn availability. Results indicate that breaking of forest land to convert it to farm land results in high Zn availability though other form of degradation maintains the available Zn.

Potassium (in ppm): Potassium that's dissolved in soil water (water soluble) considered readily available for plant growth. It is held on clay particles' exchange sites, which are found on the surface of clay particles. Called exchangeable K, this is the form of K measured by the routine soil testing procedure [16-18]. Madhya Pradesh state agriculture department of Rewa division presented the various limit of available potassium or Potash in for health quality status of soil, which are as follows:

Low level of K in ppm < 40,

Medium level of K in ppm (40 to 80),

High level of K in ppm > 80

Results of available K in ppm for whole Parasamaniya range are 76.74 ppm and 4180 ppm for field surface soil and field underground soil respectively which indicates that there is a huge difference in K level in surface and underground soils. The results also indicate the K level of field surface soil which comes in medium level of available potash. Whereas the K level of field underground soil has very high which may be due to soil and rock formation of area and it depends on topography, and geology of the area. This means that whole range has high amount of available potash.

Iron (in ppm): It is also micro nutrient of soil analysis and it is measured in ppm (Schmidt, Thomine et al. 2020). The Madhya Pradesh Agriculture department of Rewa division prescribes the sufficiency limit of iron element affecting the vegetation density. These are:

If available Fe < 4.5 ppm, deficient,

If available Fe > 4.5 ppm, sufficient.

The results of available Fe for whole Parasamaniya range indicate that the field surface soil has the value of iron 64.54 ppm, which indicates that whole area does not suffer the deficiency of iron but it is more than sufficient. Whereas the results also indicate there is significantly huge amount of iron present in field underground soil (11292 ppm).This may be due to hilly area and rocky texture of underground soil. Hence management strategy needs to be designed before cultivation practices started.

Manganese (in ppm): Manganese (Mn) is an essential plant nutrient, important for several physiological processes, particularly photosynthesis. Manganese deficiency is a widespread problem, most often occurring in sandy soils, organic soils with a pH above 6 and heavily weathered, tropical soils. It is typically worsened by cool and wet conditions [19]. The Madhya Pradesh Agriculture department of Rewa division prescribed the adequacy limit of Mn element affecting the vegetation density. These are:

If available Mn < 2 ppm deficiency,

If available Mn > 2 ppm, soil is adequate with Mn.

The result of observed value of available Mn for field surface soil is 10.45 ppm which comes under sufficient category. It means that whole area is sufficient Mn micro-nutrient. The result also indicates that digging of land i.e. when Field underground soil sample was analysed, we observed the huge amount of Mn (249.49ppm). This may be due to hilly area and rocky texture of underground soil.

Copper (in ppm): It is also the one of micro nutrient and activates enzymes and catalyzes lignin synthesis and it is also required in the process of photosynthesis, is essential in plant respiration and assists in plant metabolism of carbohydrates and proteins. The Madhya Pradesh Agriculture department of Rewa division prescribes the soil health parameter for Cu deficiency. These are:

If available Cu < 0.2 ppm, deficiency in Cu nutrient,

If available Cu > 0.2 ppm, sufficient in Cu nutrient.

The result of observed value of available Cu for field surface soil is 1.22 ppm which comes under sufficient category. The field underground soil has thee Cu value is 1.35ppm which indicate the Cu availibility is almost equally and sufficiently distributed in the Parasamaniya region. This indicates that fields do not require Cu as a micro nutrient to improve the soil quality agriculture.

Cadmium (in ppm): It is also toxic to plant and analyzed and expressed in ppm. The critical limit of cadmium in the soil is 3-8 ppm [20]. The results for average Cd analysis of soil of Parasamaniya range indicate that average observed value of Cd is 0.52 which falls under safe limit. This result indicated that the Parasamaniya region does not have Cd contamination.

Lead (in ppm): It is toxic to plant and analyzed and expressed in ppm.

If available Pb < 0.2 ppm, deficiency,

If available Pb > 0.2 ppm, sufficient.

The results for the average available Pb in the soil of Parasamaniya range is 5.95 ppm which falls under sufficiency limit and it is reported that the Pb is not required as a micro nutrient to improve the crop quality. This limit of Pb is below the hazardous level to cause any adverse health effect.

Analysis of heavy metals in *Brassica comprestis* crop

The Heavy metal content present in the Brassica comprestis crop plants in the field of Parasamaniya Platue are analyzed and presented in Table 3.

Zinc (in ppm): It is the micro element of soil analysis and it is measured in part per million (ppm). The Madhya Pradesh State

Table 3: The Heavy metal content present in the *Brassica comprestis* plant sample collected from Parasamaniya region.

Soil Type	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Cd (ppm)	Pb (ppm)	K (ppm)
Root	0	79.81	0	0	0.046	0.31	13687
Stem	11.07	29.51	3.41	1.34	0.043	0.16	11537
Seeds	10.21	7.98	12.28	2.00	0	0.05	0
Average :-	**7.09**	**39.1**	**5.23**	**1.11**	**0.029**	**0.17**	**8408**

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Agriculture department of Rewa division presented the sufficiently of zinc element for the fertility of soil and it is as follows:

If available Zinc < 0.5 ppm deficient,

If available Zinc > 0.5 ppm sufficient.

The average available Zn in Brassica comprestis plant of Parasamaniya region is 7.09 ppm, which shows that Brassica plant has more than sufficient Zn availability.

Iron (in ppm): Iron is an essential nutrient for plants. It functions to accept and donate electrons and plays important roles in the electron-transport chains of photosynthesis and respiration. But iron is toxic when it accumulates to high levels (Connolly and Guerinot 2002). The Madhya Pradesh Agriculture department of Rewa division prescribes the sufficiency limit of iron element affecting the vegetation density. These are:

If available Fe < 4.5 ppm, deficient,

If available Fe > 4.5 ppm, sufficient.

The results of available Fe for whole Parasamaniya range indicate that average value of iron 39.1 ppm, which indicates that Brassica plant has more than sufficient Fe in root (79.81ppm) and stem (29.51ppm) but seed has adequate Fe (7.98ppm) and good for health.

Manganese (in ppm): This is an essential cofactor for the oxygen-evolving complex (OEC) of the photosynthetic machinery, catalyzing the water-splitting reaction in photo system II (PSII). Mn deficiency is a serious, widespread plant nutritional disorder in dry, well-aerated and calcareous soils, as well as in soils containing high amounts of organic matter, where bio-availability of Mn can decrease far below the level that is required for normal plant growth [21]. The Madhya Pradesh Agriculture department of Rewa division prescribed the adequacy limit of Mn element affecting the vegetation density. These are:

If available Mn < 2 ppm deficiency,

If available Mn > 2 ppm, soil is adequate with Mn.

We observed the average value of available Mn for whole *Brassica comprestis* plant is 5.23 is which comes under adequate category. It means that whole area is sufficient in Mn micro-nutrient. The result also indicates that root has 0 ppm of Mn whereas stem and seed has 3.41 ppm and 12.28 ppm respectively.

Copper (in ppm): It is also the one of micro nutrient for plant growth and development analyzed and expressed in ppm. The Madhya Pradesh Agriculture department of Rewa division prescribes the soil health parameter for Cu deficiency. These are:

If available Cu < 0.2 ppm, deficiency in Cu nutrient,

If available Cu > 0.2 ppm, sufficient in Cu nutrient.

The results for *Brassica comprestis* plants of Parasamaniya range indicate that average observed value of Cu is 1.11 which falls under sufficiency limit. We also observed that the Cu amount varies throughout the Brassica plant (Table 3).This indicates that the Brassica plants have the ability to utilize Cu from soil and store in stem and seed efficiently.

Cadmium (in ppm): Cd is highly toxic to plant. The critical limit of cadmium in the soil is 3-8 ppm. The average value of Cd in *Brassica comprestis* plant is 0.029ppm which is prescribes as safe level.

Lead (in ppm): It is toxic to plant and analyzed and expressed in ppm.

If Pb level < 0.2 ppm, deficiency in Pb,

If Pb level > 0.2 ppm, sufficient in Pb.

The results for the average available Pb in the Brassica plants is 0.17ppm which falls under sufficiency limit and it is reported that the Pb is not required as a micro nutrient to improve the crop quality. This limit of Pb is below the hazardous level to cause any adverse health effect.

Summary

Knowing the pH of the soil can help you choose the right plants and the necessary treatment for your soil to achieve better crop yields. Our results show that for all types of soil samples, keeping the soil pH within the normal limit, the pH ranged from 7.21 to 7.11, with an average pH of 7.17. The electrical conductivity (in mmhos/cm) of all soil types remains within the normal limit (0.27 to 0.45) as EC<1.0. The results of OC analysis show that the organic matter content of the different soil samples ranges from 0.48 to 0.53. This indicates that the observed value of organic matter in the subsurface soils of the field is low, while the OC content in the surface soils and the soils near the field is in the medium range. The results of available nitrogen in all soil samples indicate that the available nitrogen in the form of N2< 250 kg/ha is at low level. The observed value of available nitrogen in the subsurface soil of the field (218.78 kg/ha) and in the adjacent soils (225.19 kg/ha) is very close to the mean value of 207.32 kg/ha, but decreases significantly in the surface soil of the field (178 kg/ha). The observed value indicates that we need to add nitrogen fertiliser to improve the available nitrogen in the fields of Parasamaniya region for better crop yield. The results of available phosphorus in the soil samples show that the available phosphorus is of medium status as the average available P2O5 is 39.31 kg/ha. This may be due to the soil and rock characteristics of the area and depends on the topography and geology of the area. Further addition of phosphorus fertilisers should be avoided as a management strategy. The K content of the field surface soil is in the middle range of available potash. The K content of the subsurface field soil, on the other hand, is very high, which may be due to the soil and rock formation of the area and depends on the topography and geology of the area. This means that the entire area has a high amount of available potash.

Our results indicate that the available zinc and iron in the soils is too high. This means that the entire Parasamaniya area is contaminated with zinc and iron. Therefore, there should be no addition of iron and zinc as micronutrients. It was also found that manganese and copper are present in sufficient quantity in the soil of the Parasamaniya region and should not be added externally. The average cadmium and lead content in the soil is 0.052 ppm and 5.95 ppm respectively and in the *Brassica comprestis* plant is 0.029 ppm and 0.17 ppm respectively, which is a safe level of quantity in the entire region and will not contaminate the ecosystem. Further

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experiments need to be conducted in the laboratory using tissue culture and biochemical analysis to study the adverse effects of metals on Brassica plants, as most farmers are not aware of the toxic effects of these metals on their crops and health [23-25].

Conclusion

Our results show that for all types of soil samples, keeping the soil pH within the normal limit, the pH ranged from 7.21 to 7.11, with an average pH of 7.17. The results of OC analysis show that the organic matter content of the different soil samples ranges from 0.48 to 0.53. This indicates that the observed value of organic matter in the subsurface soils of the field is low, while the OC content in the surface soils and the soils near the field is in the medium range. The observed value indicates that we need to add nitrogen fertiliser to improve the available nitrogen in the fields of Parasamaniya region for better crop yield. The K content of the field surface soil is in the middle range of available potash. The K content of the subsurface field soil, on the other hand, is very high, which may be due to the soil and rock formation of the area and depends on the topography and geology of the area. Our results indicate that the available zinc and iron in the soils is too high. This means that the entire Parasamaniya area is contaminated with zinc and iron.

Acknowledgement

Funding for the current work was supported by UGC, Government of India is gratefully acknowledged. All the experiments were performed at Department of botany, Government Girls Degree College Rewa MP and Department of Zoology, Government VPG College Maihar, Satna MP. Dr. Vipin Kumar Kashyap is acknowledged for the excellent technical support in performing experiment. We also acknowledge to Mr. G.S. Tagore for ICP-Mass spectroscopy (QQQ) at department of soil science, Jawaharlal Nehru Agriculture University Jabalpur, MP.

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