Curriculum Vitae

Name : Dr. Anindita Seth (Gupta)

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Floral City, House no.-121,
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A. Working experience (2009-2019)

1. **Co-principle investigator/ Co-PI (2018)** of "Centre of excellence in nanotechnology in agriculture' in sustainable agriculture division of TERI-Deakin Nanobiotechnology center, Gurgaon, Haryana, India.
2. **Research Associate/ equivalent to Scientist-B (2018) for 6 months** in sustainable agriculture division of TERI-Deakin Nanobiotechnology center, The Energy and Resources Institute (TERI), New Delhi-Gurgaon (June-Dec, 2018), India.
3. **Postdoctoral Fellow (2016-2018) for 2 years** in the Department of Soil and Water Sciences, The Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot, Israel.
4. **Block-Technology Manager/BTM (2014-2015) for 1 year** under ATMA project of Government of India in Chinsurah-Mogra Block, Hooghly district, West Bengal, India.
5. **Research Associate (2012-2013) for 6 months** for in the research project entitled "AICRP on Micronutrients and Secondary Nutrients and Pollutant elements in soils and crops" funded by Indian Council of Agricultural Research (ICAR), under Scientist-*in*-Charge Prof. G. C. Hazra at D/R, BCKV, Kalyani, West Bengal, India.
6. **Senior Research Fellow (2010-2012) for 2 years** for the project entitled "GPS-GIS based soil fertility maps for selected districts of the country for precise fertilizer recommendation for farmers of India" funded by Deptt. of Agriculture & Co-operation (DAC), Govt. of India, Ministry of Agriculture, under Principle Investigator Prof. Biswapati Mandal at D/R, BCKV, Kalyani, West Bengal, India.
7. **Senior Research Fellow (2010) for 2 months** for the project entitled "Undertake measurements in Rice Fields of Bihar and West Bengal to determine CH_4 emission factors" sanctioned by the UNDP-GEF, Ministry of Environment and Forests, Govt. of India, under Principle Investigator Prof. Biswapati Mandal at D/R, BCKV, Kalyani, and West Bengal, India.
8. **Research Student (2009-2010) for 6 months** for the project entitled "Studies on the effect of concentrated manure- a naturally occurring organics on betelvine and its rhizosphere beneficial microorganisms" under Dr. Niharendu Saha, Associate Professor, Department of Agricultural Chemistry and Soil Science, BCKV, Kalyani, West Bengal, India.

B. Research experience (2008-2018)

1. **Postdoctoral programme (2016- 2018)**
   Advisor: Professor Moshe Shenker,
   Department of Soil and Water Science,
   The Robert H. Smith Faculty of Agriculture, Food and Environment,
   The Hebrew University of Jerusalem, Rehovot-760100, Israel
   Postdoctoral research work:

- Nanotechnology for developing new generation of fertilizers.
- The K to (Ca+Mg) ratio effect on K availability for plants, splitting soil- from plant-related interactions using the Q/I approach.
- A study on Fe-bioassay to mitigate chlorosis on plant grown on calcareous soil.

2. **Doctoral programme (2011-2017)**
   Advisors: (1) Professor Biswapati Mandal
   Department of Agricultural Chemistry and Soil Science,
   Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India
   (2) Professor Ashim Chowdhury
   Department of Agricultural Chemistry and Soil Science,
   IAS, University of Calcutta, India
   Ph.D. Thesis topic:
   "Studies on the suitability of multi-nutrient extractants for estimating available nutrients in soil for nutrition of crops".
3. **Master of Science- dissertation (April, 2008- June, 2009)**
   Supervisor: Professor Ashim Chowdhury
   Institute of Agricultural Science, University of Calcutta, West Bengal, India
   M.Sc. Dissertation Title:
   "Studies on the effect of Fipronil on some microbiological parameters and enzymatic activity of soil".

C. Summary of research work

1. A study was conducted to find the suitability of multi-nutrient extractants *viz.* Mehlich 3, AB-DTPA, Modified Morgan, Morgan and tailored CDTA-Glycerol for estimating available soil nutrients *viz.* P, K, Ca, Mg, S, B, Zn, Fe, Cu and Mn in relation to their nutrition of rice and wheat. There determined the critical limits of P, K, S, B and Zn, as estimated by five multi-nutrient extractants and respective conventional extractants as well as N by only traditional extractant for rice and wheat grown on Inceptisols and Alfisols using twenty series of each soil order. The efficiency of multi-nutrient extractants and respective conventional extractants was compared for estimating P, K, Ca, Mg, S, B, Zn, Fe, Cu and Mn in two types of soil and also their correlations were determined. Again, the correlationship between multi-nutrient extractants removable nutrients with soil properties like pH, organic C, CEC and clay content was established. Finally, the suitability of multi-nutrients was calibrated by correlations study between multi-nutrient extractant removable nutrients with plant parameters like dry-matter yield, Bray's percent yield, concentration and uptake of nutrients by rice and wheat.

2. An investigation was done applicability of nano-hydroxyapatite in clayey, sandy and calcareous soil for P nutrition of maize. The movement, adsorption and stability of nano-hydroxyapatite was also studied in comparison with soluble P fertilizer.

3. A study was conducted on the energy of K^+ to (Ca^{2+} + Mg^{2+}) exchange [ΔF] in soils, the intensity factor in plant K nutrition, K availability indices in clayey and sandy soils by evaluating quantity-intensity (Q/I) characteristics curve of K, potential buffering capacity (PBC) of soil, activity ratio of K (AR_K). It was also elucidated whether the ratio $K^+/(Ca^{2+} + Mg^{2+})$ affects K nutrition of plants through plant physiological interactions, such as competition, or through soil-related interactions and the influence of various ratios of K concentration to (Ca+Mg) concentration on the growth and K uptake of tomato plants was examined in soil and hydroponic culture.

4. An experiment was conducted on bioassay for screening Fe-chelates to mitigate chlorosis of peanut plant grown on Rendzina soil.

5. A study was done on the effect of increasing doses of Fipronil, a pyrazole insecticide, on dynamics of microbial biomass carbon (MBC), soil respiration, FDA, dehydrogenase, phosphatase, sulfatase, *β*-glucosidase activity of a soil.

D. Skills and proficiency

- **Equipment expertise:**
  Well equipped with ICP-AES, AAS, UV-Vis Spectrophotometer, automatic nitrogen distillation system (KEL Plus), Flame Photometer, pH Meter, Conductivity-meter, Calcimeter, Chloride-analyser, Chlorophyll-meter and etc.

- **Analytical experience:**

1. Conversant with the methodology for analyzing different physical, chemical, physico-chemical and biological parameters of soil.
2. Experienced in analysis of pH, EC, hygroscopic water, CEC, textural class, $CaCO_3$ content, HCO_3^-, Cl^-, salinity, quantity-intensity isotherm of K in soil and etc.
3. Efficient to assess nutrient content of N, P, K, Ca, Mg, S, B, Zn, Fe, Cu, Mn, etc. in soil and plant.
4. Experienced in hydroponic and pot experiment.
5. Familiar with investigation on mobility, adsorption and incubation of nutrients and nano-fertilizers in soil.
6. Worked on analysis of microbial biomass carbon (MBC), soil respiration (basal and substrate induced respiration).
7. Studied the enzymatic activity like dehydrogenase, sulfatase, *β*-glucosidase, alkaline and acid-Phosphatase, fluorescein diacetate hydrolysing activity (FDA) etc. in soil.
8. Worked with SPSS and JMP for statistical data analysis.

- **Field experience**
  Expert in performing GPS-based soil-survey and soil sampling as done from 13 districts of state West Bengal, India as well as experienced to carry out pot experiments, on-farm trial and field level demonstration experiments by communicating farmers in different sites of West Bengal, India.

- **Working experience as extension personnel**
  Experienced to work with farmers based on their strength or weakness by creating farmers-groups and mobilizing them to implement innovative research idea or technology by doing farmer-interaction, training programme and demonstration.

- **Language proficiency and computer skill**
  Fluency in English and Hindi, and well literate in computer.

E. Academic profile

Course/ Study	Name of Institution	Board/ Council/ University	Year of Passing/ Joining	% of Marks/ Grade Score/ etc.	Division/ Class / Grade
• **Postdoctoral Research (Soil and Water Sciences)**	The Robert H. Smith Faculty of Agriculture, Food and Environment	The Hebrew University of Jerusalem, Rehovot-760100, Israel	2016-2018	**Advisor;** Prof. Moshe Shenker Soil & Water Sc., F/Ag, The Hebrew University of Jerusalem, Israel	
• **Ph.D. (Agricultural Chemistry and Soil Science)**	IAS, University of Calcutta and BCKV, Kalyani	University of Calcutta, India	2017 (PhD Degree awarded)	**Supervisors:** Prof. Ashim Chowdhury, IAS, Univ. of Calcutta Prof. Biswapati Mandal, BCKV, Kalyani, India	
• **M. Sc. (Ag.) in Agricultural Chemistry and Soil Science**	Institute of Agricultural Science,	University of Calcutta, India	2009	7.25 (10.0 OGPA Scale)	B
• **B. Sc. (Hons.) in Chemistry**	Surendranath College. Kolkata	University of Calcutta, India	2007	56%	II
• **Higher Secondary (10+2)**	Kalyani University Experimental High School	West Bengal Council of Higher Secondary Education	2004	69.6%	I
• **Secondary**	Kalyani University Experimental High School	West Bengal Board of Secondary Education	2002	82%	I

F. Publications

- **Research Articles (2015-)**

1. Ruma Das, Biswapati Mandal, Dibyendu Sarkar, Amit Kumar Pradhan, Ashim Datta, Dhaneshwar Padhan, **Anindita Seth**, Rahul Kumar, Nirmal De, V. N. Mishra, K. B. Polara, Sanjay Sharma, N. P. Thakurj, Dileep Kachroo, M. Ray, Anil Sharma, K. P. Patel, Lalit Mohan, Garnayak W.N.Narkhedeo, “Boron availability in soils and its nutrition of crops under long-term fertility experiments in India” **Geoderma**, 351: 116-129, **2019.**

2. **Anindita Seth**, Dibyendu Sarkar, Reginald Ebhin Masto, Kaushik Batabyal, Susmit Saha, Sidhu Murmu, Ruma Das, Dhaneshwar Padhan and Biswapati Mandal, “Critical Limits of Mehlich 3 Extractable Phosphorous, Potassium, Sulfur, Boron and Zinc in Soils for Nutrition of Rice (Oryza sativa L.)”, **Journal of Soil Science and Plant Nutrition,** 18 (2): 512-523, **2018.**

3. **Anindita Seth,** Dibyendu Sarkar, Ashim Datta, Biswapati Mandal, Ashim Chowdhury, Reginald Ebhin Masto, Arun Kumar Chakravarty, Gora Chand Hazra, Shrikant Badole, Kaushik Batyabal, and Susmit

Saha "Suitability of complex extractants for assessment of available soil zinc for nutrition of rice (Oryza sativa L.) in subtropical India", **Soil Science,** 182(1): 28-35, **2017.**

4. Susmit Saha, Mahasweta Chakraborty, Dhaneshwar Padhan, Bholanath Saha, Sidhu Murmu, Kaushik Batabyal, **Anindita Seth**, G.C. Hazra, Biswapati Mandal, R.W. Bell "Agronomic biofortification of zinc in rice: Influence of cultivars and zinc application methods on grain yield and zinc bioavailability", **Field Crops Research,** 210: 52-60, **2017.**
5. Shrikant Badole, Ashim Datta, Nirmalendu Basak, **Anindita Seth**, Dhaneshwar Padhan & Biswapati Mandal "Liming influences forms of acidity in soils belonging to different orders under subtropical India", **Communications in Soil Science and Plant Analysis**, 46:2079–2094, **2015.**
6. **Anindita Seth**, Saswati Pradhan, Swarnali Purkait, Suchismita Sinha and Ashim Chowdhury, "Effect of Fipronil, a pyrazole insecticide, on microbial biomass carbon, soil respiration, FDA and dehydrogenase activity of soil" **International Journal of Advanced Biological Research,** 6(3): 352-356, **2016.**

- **Abstracts (2011-)**

1. **Anindita Seth**, Roee Gothelf and Moshe Shenker, "The K to (Ca+Mg) ratio effect on potassium availability for plants – splitting soil- from plant-related interactions" Geophysical research abstracts, vol. 20, **EGU2018-9425-3, EGU General Assembly 2018**.
2. Moshe Shenker and **Anindita Seth**, "Potassium availability in soils and the use of the Q/I approach – moving from theory to nation-wide realization", Geophysical research abstracts, vol. 20, **EGU2018-9716-2, EGU General Assembly 2018**.
3. **A. Seth**, D. Padhan, B. Mandal, K. Karmakar and N. Saha. "Microbial biodiversity in soils under organic farming system". **3rd Indian Biodiversity Meet- An International Conference**, P. 84-85, **2015**.
4. **A. Seth**, A. Datta, I. Das, S. Saha, K. Beura, A. K. Pradhan, R. Das, S. P. Badole and Biswapati Mandal, "Available Sulfur Status in soils of Jalpaiguri, North Dinajpur and Nadia District, West Bengal", Proc. **100th Science Congress**, Part II, pp-246 (G-3), **2013**.
5. **Anindita Seth**, Ashim Chowdhury and Biswapati Mandal, "Effect of Fipronil on FDA and Dehydrogenase Activity of Soil", Proc. **100th Science Congress**, Part II, pp-250 (G-8), 2013.
6. S.P. Badole, Ashim Datta, **Anindita Seth** and Biswapati Mandal, "Effects of Liming on Different Forms of Acidity in Soils from Various Agro-Climatic Zones of West Bengal", Proc. **100th Science Congress**, Part II, pp-279 (G-45), **2013**.
7. Amit Kumar Pradhan, Kasturikasen Beura, **Anindita Seth**, Ipsita Das, Susmit Saha, Ashim Datta, Durgesh Kumar Singh, G.C. Hazra and Biswapati Mandal, "Distribution of Available micronutrients in Soils of Nadia District, West Bengal", Proc. **100th Science Congress**, Part II, pp-248 (G-6), **2013**.
8. Kasturikasen Beura, Amit Kumar Pradhan, **Anindita Seth**, Ipsita Das, Susmit Saha, Ashim Datta, G.C. Hazra and Biswapati Mandal, "Distribution of Available N, P, K, S in Soils of Nadia District, West Bengal", Proc. **100th Science Congress**, Part II, pp-338 (K-18), **2013**.
9. **Anindita Seth**, Ashim Datta, Nirmalendu Basak , Bholanath Saha, Susmit Saha, Ipsita Das, Shrikant Badole, Ruma Das, Sajal Pati, Gora Chand Hazra and Biswapati Mandal, "Studies on the status of available zinc and sulfur with the variation of pH and organic carbon in some Inceptisol and Alfisol of West Bengal", **Indian Society of Soil Science, 77th Annual Convention**, pp-48, **2012**.

10. G.C. Hazra, Bholanath Saha, Susmit Saha, **Anindita Seth**, Sushanta Saha, Debabrata Dhar, Sidhu Murmu and Biswapati Mandal, "Influence of Zn fertilization on bioavailability of Zn in edible rice" **Indian Society of Soil Science, 77th Annual Convention**, pp-136, **2012**.

11. Bholanath Saha, G.C. Hazra, Susmit Saha, Partha Deb Roy, **Anindita Seth**, Sushanta Saha and Biswapati Mandal, "Influence of Zn Fertilization on Bioavailability of Fe in Edible Rice" **Indian Society of Soil Science, 77th Annual Convention**, pp-137, **2012**.

12. Shrikant Badole, Ashim Datta, Shreyasi Gupta Choudhury, Nirmalendu Basak, Sabyasachi Das, **Anindita Seth** and Biswapati Mandal, "Deep soil organic carbon -an important component of global C-cycle and its stabilization mechanisms" **Indian Society of Soil Science, 77th Annual Convention**, pp-239, **2012**.

13. **Anindita Seth**, Ashim Chowdhury and Biswapati Mandal, "Influence of Fipronil on Some Microbiological Parameters and Enzymatic Activity of Soil", **Indian Society of Soil Science, 76th Annual Convention**, pp-73, **2011**.

- ***Technical Bulletin***
  Contributor in Technical bulletin "**Soil Atlas for available micronutrient**" for 14 districts of West Bengal published by Bidhan Chandra Krishi Viswavidyalaya in collaboration with National Atlas & Thematic Mapping Organisation and Indian Council of Agricultural Research **(2017)**.

G. Active participation and training exposure

1. **Participated and presented in 6 days general assembly of European Geosciences Union (EGU, 2018)** organised in Austria Center Vienna, Austria, Europe.
2. **Participated in 4 days training programme (2015)** of "Soft skill development for Extension Personnel" organised by Extension Education Institute (EEI) of Assam Agricultural University, Jorhat, Assam in collaboration with SAMETI, Ramkrishna Mission, Narendrapur, Kolkata.
3. **Presented poster on a research topic (2013)** in "100th Indian Science Congress Association (ISCA)" held in University of Calcutta, Kolkata, India
4. **Participated in poster presentation (2012)** in "77th Annual Convention of Indian Society of Soil Science (ISSS)" held in Punjab Agricultural University, Ludhiana, Punjab, India.
5. **Certified for attending two days of training workshop (2012)** on "High tech. vegetable cultivation for uniform economic return" organized by Center for Testing & Training for Providing Technical back up to the beneficiaries for Agri/Horti Development, under coordinator Prof. Ashim Chowdhury, IAS, University of Calcutta, India.
6. **Participated in poster presentation (2011)** in "76th Annual Convention of Indian Society of Soil Science (ISSS)" held in University of Agricultural Science, Dharwad, Karnataka, India.
7. **Assisted and demonstrated in a seven days (2010) training programme** entitled "Soil testing and Fertilizer recommendation" sponsored by National Bank for Agriculture and Rural Development (NABARD), Kolkata under programme coordinator Dr. Niharendu Saha, Directorate of Research, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, India.

H. Fellowships and Awards

1. Fellowship from Govt. of Israel (2016).
2. Fellowship from Indian Council of Agricultural Research (2012).

3. Qualified RET (Ph.D. entrance test) with 1st position (2011).
4. Fellowship from DAC, Ministry of Agriculture, Govt. of India (2010).
5. Fellowship from UNDP-GEF, Ministry of Environment and Forests, Govt. of India (2010).

I. Reviewer of peer reviewed journal

1. South African Journal of Plant and Soil

J. Research Interest

- Soil chemistry and plant nutrition
- Soil fertility and soil health.
- Application of nano-technology for plant nutrition.
- Innovative research for economic benefit of country and sustainable future

K. Teaching experience

Acted as teacher for very short period of time.

L. Personal details

Date of Birth	:	24.08.1986
Nationality	:	Indian
Category	:	General
Birth place	:	West Bengal

Anindita Seth (Gupta)

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Anindita Seth

Postdoctoral Researcher, Department of Soil and Water Sciences,
Hebrew University of Jerusalem

	All	Since 2014
Citations	19	19
h-index	3	3
i10-index	0	0

TITLE	CITED BY	YEAR
Critical limits of Mehlich 3 extractable phosphorous, potassium, sulfur, boron and zinc in soils for nutrition of rice (Oryza sativa L.) A Seth, D Sarkar, RE Masto, K Batabyal, S Saha, S Murmu, R Das, ... Journal of soil science and plant nutrition, 0-0	6	2018
Liming influences forms of acidity in soils belonging to different orders under subtropical India S Badole, A Datta, N Basak, A Seth, D Padhan, B Mandal Communications in Soil Science and Plant Analysis 46 (16), 2079-2094	6	2015
Agronomic biofortification of zinc in rice: Influence of cultivars and zinc application methods on grain yield and zinc bioavailability S Saha, M Chakraborty, D Padhan, B Saha, S Murmu, K Batabyal, A Seth, ... Field Crops Research 210, 52-60	5	2017
Suitability of complex extractants for assessment of available soil zinc for nutrition of rice (Oryza sativa L.) in subtropical India A Seth, D Sarkar, A Datta, B Mandal, A Chowdhury, RE Masto, ... Soil Science 182 (1), 28-35	2	2017
Boron availability in soils and its nutrition of crops under long-term fertility experiments in India R Das, B Mandal, D Sarkar, AK Pradhan, A Datta, D Padhan, A Seth, ... Geoderma 351, 116-129		2019
The K to (Ca+ Mg) ratio effect on potassium availability for plants--splitting soil-from plant-related interactions A Seth, R Gothelf, M Shenker EGU General Assembly Conference Abstracts 20, 9425		2018
Potassium availability in soils and the use of the Q/I approach--moving from theory to nation-wide realization M Shenker, A Seth EGU General Assembly Conference Abstracts 20, 9716		2018
Effect of Fipronil, a pyrazole insecticide, on microbial biomass carbon, soil respiration, FDA and dehydrogenase activity of soil SSAC Anindita Seth, Saswati Pradhan, Swarnali Purkait International Journal of Advanced Biological Research 6 (3), 352-356		2016

Suitability of Complex Extractants for Assessment of Available Soil Zinc for Nutrition of Rice (*Oryza sativa* L.) in Subtropical India

Anindita Seth,[1] Dibyendu Sarkar,[2] Ashim Datta,[2] Biswapati Mandal,[2] Ashim Chowdhury,[1] Reginald Ebhin Masto,[3] Arun Kumar Chakravarty,[4] Gora Chand Hazra,[2] Shrikant Badole,[2] Kaushik Batyabal,[2] and Susmit Saha[2]

ABSTRACT:
We evaluated the efficiency of six complex extractants such as diethylenetriaminepentaacetic acid (DTPA), Mehlich 3, ammonium bicarbonate–DTPA (AB-DTPA), modified Morgan, Morgan and diaminocyclohexanetetracetic acid-glycerol (CDTA) as to their suitability for assessing available zinc (Zn) status in soils of the Inceptisols and Alfisols soil orders for nutrition of rice (*Oryza sativa* L.). Twenty soils from each of the two soil orders were analyzed for extractable Zn content and used to grow rice with three levels of Zn (0, 5, and 10 kg ha^{-1}). The relative efficiency of the Zn extractants followed the order AB-DTPA > Mehlich 3 > DTPA > CDTA > modified Morgan > Morgan in soils from the Inceptisols soil order and Mehlich 3 > AB-DTPA > modified Morgan > DTPA > Morgan > CDTA in soils classified as Alfisols. The extractable soil Zn was significantly correlated with soil organic C and clay content. All the soils showed significant response to Zn application in terms of increases in dry matter yield, Zn concentration, and plant uptake. Of the six extractants tested, AB-DTPA and Mehlich 3 were the best for assessing plant available Zn contents for nutrition of rice. The critical limits of Mehlich 3 and AB-DTPA extractants for getting higher responses of rice to Zn application were 1.2 and 1.0 μg g^{-1} in Inceptisols and 2.0 and 1.5 μg g^{-1} in Alfisols, respectively.

Key Words: AB-DTPA, alfisols, CDTA, DTPA, inceptisols, mehlich 3, modified morgan, morgan

(Soil Sci 2017;182: 28–35)

Zinc (Zn) is an essential micronutrient required for the normal growth and development of plants (Marschner, 1983). Widespread Zn deficiency of crops has been reported from different parts of the world including India (Mandal et al., 2000; Fageria and Baligar, 2005). Zinc deficiency is commonly observed in light-textured acidic soils, in soils with high amounts of calcium carbonate and oxides of Fe and Al, and also in soils with low organic matter content (Clark, 1982; Fageria et al., 2002; Mandal et al., 1992; Mandal et al., 2000). Zinc deficiency is very common in soils growing rice (*Oryza sativa* L.) and causes serious nutritional disorder, thus limiting yield of the crop (Slaton et al., 2005; De Datta, 1981). In subtropical India, rice is the major crop in the fine-textured alluvial soils belonging to the soil orders Inceptisols and moderately weathered acidic Alfisols. These soils not only have inherently low contents of Zn (Mandal and Hazra, 1997) but are also subjected to increasing cropping intensity with high-yielding rice varieties and the high use of micronutrient free NPK fertilizers. These practices cause a further depletion of native soil Zn and accentuate the deficiency (Mandal and Mandal, 1986).

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[2]*Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India.*

[3]*Environmental Management Division, Central Institute of Mining and Fuel Research, FRI, Dhanbad, India.*

[4]*Max-Planck Institute, Frankfurt, Germany; and Department of Chemistry, Dumdum Motijhil College, Kolkata, West Bengal, India.*

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Several extractants have been tested for assessing the available Zn content of soils for Zn nutrition of crops. As with many other micronutrient cations, the most practical soil testing approach for Zn is the use of a multinutrient extractant (Sims and Johnson, 1991). The diethylenetriaminepentaacetic acid (DTPA) extraction (0.005 *M* DTPA + 0.01 *M* $CaCl_2$ + 0.1 *M* triethanolamine, pH 7.3 [Lindsay and Norvell, 1978]) is one of the most commonly used for assessing Zn availability in soils. The DTPA ligands form water-soluble Zn complexes and thereby decrease Zn^{2+} activity in soil solution. This facilitates desorption of Zn from soil to replenish soil solution Zn^{2+}. The buffered pH and presence of soluble Ca^{2+} prevent excessive dissolution of $CaCO_3$, avoiding the release of unavailable Zn occluded by this solid phase. Despite these advantages, it is somewhat difficult to use the DTPA procedure in a routine soil testing laboratory because it requires a 2-h shaking period and is used only for four essential elements (Fe, Mn, Cu, and Zn). To overcome these problems, Soltanpour and Schwab (1977) modified the DTPA extractant by combining it with 1.0 *M* ammonium bicarbonate (AB) to extract P, K, Ca, and Mg in addition to Zn, Cu, Fe, and Mn; adjusting the pH from 7.3 to 7.6; and shortening the shaking time to 15 min.

Mehlich 3 (0.2 *M* CH_3COOH + 0.25 *M* NH_4NO_3 + 0.015 *M* NH_4F + 0.013 *M* HNO_3 + 0.001 *M* EDTA, pH 2.5), which is also a multinutrient extraction, is known to extract Zn by H^+ and NH_4^+ ions and formation of Zn-EDTA complexes (Mehlich, 1984). The lower pH of Mehlich 3 also promotes dissolution of Zn hydroxides in soils (Vidal-Vazquez et al., 2005). Morgan (1941) used the first universal soil extractant (0.72 *M* Na-acetate + 0.52 *M* CH_3COOH, pH 4.8), which allowed for "rapid microchemical" tests to determine readily available plant nutrient elements in soil for the purpose of estimating the fertilizer needs of crops. The Morgan extractant was modified to increase its usefulness in analyzing soils with ranges of fertility by substituting NH_4 for Na to facilitate the extraction of K in a wider variety of soils (McIntosh, 1969).

Recently, Seth (2016) tailored diaminocyclohexanetetracetic acid-glycerol (CDTA), a new complex multinutrient extractant that combines 0.002 *M trans*-CDTA, 0.05 *M* glycerol, 0.1 *M* NH_4-acetate, and 0.01 *M* NH_4F, buffered at pH 4.8. The premise for this extractant is the CDTA forms stronger complexes with almost all metals than does EDTA or DTPA, and the low buffering pH (4.8) could extract

Journal of Soil Science and Plant Nutrition, 2018, 18 (2), 512-523
RESEARCH ARTICLE

Critical limits of Mehlich 3 extractable phosphorous, potassium, sulfur, boron and zinc in soils for nutrition of rice *(Oryza sativa L.)*

Anindita Seth[1], Dibyendu Sarkar[2], Reginald Ebhin Masto[3], Kaushik Batabyal[2], Susmit Saha[2], Sidhu Murmu[2] , Ruma Das[4], Dhaneshwar Padhan[2] , Biswapati Mandal[2]

*[1]Department of Soil and Water Sciences, The Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot-760 100, Israel. [2]Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, West Bengal-741 252, India. [3]Environmental Management Division, Central Institute of Mining and Fuel Research, FRI, Dhanbad-828 108, India. [4]Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute (IARI), Pusa Campus, New Delhi 110 012, India. *Corresponding author: anindita.asg@gmail.com*

Abstract

We evaluated the critical limits of P, K, S, B and Zn in Inceptisols and Alfisols for nutrition of rice (*Oryza sativa* L.) using Mehlich 3 as an extractant. Three levels, each of P (0, 14 and 23 mg kg^{-1} soil), K (0, 23 and 36 mg kg^{-1} soil), S (0, 4.5 and 9.0 mg kg^{-1} soil), B (0, 0.5 and 1.0 mg kg^{-1} soil) and Zn (0, 2.3 and 4.5 mg kg^{-1} soil) were applied separately to 20 Alfisols and Inceptisols each for growing rice in greenhouse. Biomass yield, concentration and uptake of those nutrients by rice were significantly influenced ($P \leq 0.01$) by the soil and rate of each of the nutrients (P, K, S, B and Zn), but not by their interactions in both the soil orders. The amount of these five nutrients as extracted from soils by Mehlich 3, alike conventional extractants, showed significant positive correlations ($P \leq 0.01$) with biomass yield, nutrients concentration and their uptake by rice plant, which indicated suitability of Mehlich 3 in predicting plant available nutrients in soil. The critical levels of Mehlich 3 extractable P, K, S, B and Zn for rice in Inceptisols were 14.7, 51.2, 22.9, 0.65 and 1.27 mg kg^{-1}; while in Alfisols those values were 8.2, 117.3, 21.9, 0.40 and 2.15 mg kg^{-1}, respectively.

Keywords: Mehlich 3, suitability, Inceptisols, Alfisols, critical limit, rice.

Field Crops Research 210 (2017) 52–60

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Agronomic biofortification of zinc in rice: Influence of cultivars and zinc application methods on grain yield and zinc bioavailability

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A R T I C L E I N F O

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A B S T R A C T

Zinc biofortification in rice can be improved by altering Zn application timing and placement and cultivar choice. We made a comprehensive assessment on this, analysing Zn, Fe and phytic acid in whole grains and processed brown, white and cooked rice obtained from six cultivars raised with Zn applied through soil and/or foliar supply at different phenological stages of the crop and measuring Zn bioavailability in cooked rice. Pathways for Zn enrichment (27.4–92.6% over control) by Zn fertilization with different application protocols and cultivars were elucidated. Such enrichment of Zn was associated with depletion in Fe (6.5–29.4%) and phytic acid (14.8–30.4%). However, the loss of Zn on processing of rice grains increased on Zn fertilization (12.6–28.7 mg kg^{-1}) because of a preferential allocation of applied Zn into bran and aleurone of the grains. Despite such loss, application of Zn caused a net increase in Zn bioavailability (52.2% over control) in the cooked product. Using the ranksum scoring technique, we found cultivar GB 1 and Zn supply through soil (basal) + 2 foliar applications achieved the most effective biofortification of Zn in rice by optimizing grain yield, and enriching Zn and its bioavailability in cooked grain with least antagonism of Fe availability.

1. Introduction

Dietary deficiencies of Zn and Fe are a serious global public health problem affecting over two billion people and causing a loss of 63 million life-years annually (Myers et al., 2014). These cases of malnutrition are more acute in populations of Africa, South and South East Asia where cereals, the major staple foods, are low in dietary Zn and Fe. Rice is of major importance particularly in South and South East Asia because it contributes more than two thirds of the energy intake of its population (Timsina et al., 2010). Zinc concentration in rice grains can be enriched by: i) biofortification with popular Zn fertilizers (Cakmak, 2009), ii) manipulating Zn transporters and ligands in rice plants (Palmgren et al., 2008; Borrill et al., 2014) and iii) efficient germplasm screening for higher bioavailable Zn (Blair 2014; Trijatmiko et al., 2016). All these methods depend on fertilizer or the soil or both as the source of Zn to produce Zn enriched grains. Soil supplied Zn is, however, limited depending upon soil properties such as pH and redox potential, contents of CO_3^{2-} and HCO_3^{-}, oxides of Fe and Al, and organic matter (Mandal and Mandal, 1990) and inherent Zn status in the upper soil layer (Tuiyogon et al., 2016). The problem of low Zn availability to plants is exacerbated when rice is grown in submerged soils (Meng et al., 2014). Application of Zn fertilizer is the most common option to overcome such problems. But recovery of applied Zn by rice hardly exceeds 2% of the applied amount (Alloway, 2008).

Tailoring Zn application protocols may help to enhance transport of applied Zn to the edible parts in plants and thus its use-efficiency. We, therefore, designed Zn application protocols using key principles of Zn nutrition of rice namely: (i) soil applied Zn after undergoing reactions with soil components, is absorbed by roots, travels through xylem to storage tissues, leaves and subsequently to grains via phloem (Forties et al., 2014) despite a number of impediments like high pH of phloem sap, chelation processes etc. (Impa and Johnson-Beebout, 2012); (ii) on the contrary, foliar applied Zn moves faster within plants but re-translocation is dependent on plant nutritional status, germplasm and plant phenological stage (Sperotto, 2013). Immature leaves are physiologically incapable of exporting nutrients until they mature, while mature leaves export nutrient directly via phloem to developing grains and other organs but are incapable of importing (Fernandez and Brown,

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Liming Influences Forms of Acidity in Soils Belonging to Different Orders under Subtropical India

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A pot experiment was conducted to study the influence of liming on changes in different forms of acidity in relation to soil properties. Thirty-six surface (0–15 cm deep) soil samples were collected from different soil orders, namely Entisols, Inceptisols, Alfisols, and Entisols of coastal saline zone of West Bengal, India, and incubated for 21 days with three doses of lime [i.e., no lime (L_0), half lime ($L_{1/2}$), and full lime (L_1)]. Results of analysis of soil showed that there were significant increases in pH in water (pH_w) and pH in 0.02 M calcium chloride ($CaCl_2$) (pH_{Ca}) (1.3 and 1.5 units) and decrease in total acidity, hydrolytic acidity, exchange acidity, electrostatically bound aluminium ($EBAl^{3+}$), and electrostatically bound hydrogen (EBH^+) upon liming being from 1.53 to 0.57, 1.40 to 0.54, 0.13 to 0.03, 0.08 to 0.01, and 0.06 to 0.02 cmol (p^+) kg^{-1}, respectively. The decrease in values of all the forms of acidity was greater in L_1 than in $L_{1/2}$ treatment under Entisols of the terai zone, followed by Entisols of coastal saline zone, Inceptisols, and Alfisols. The forms of acidity showed significant positive correlation with each other but negative correlation with pH_w and pH_{Ca}, except for EBH^+.

Keywords Forms of acidity, lime requirement, liming, soil properties

Introduction

Acidic soils are an impediment to agricultural production. Soil acidity is the major factor that restricts crop growth in large areas of the world (Shainberg et al. 1989). Acidic soils occupy about 3.95 billion ha and account for 30 percent of the world's ice-free land area (Vonuexküll and Mutert 1995). Particularly in humid tropical and subtropical climatic zones, acidic soils are predominantly found, which hinders many countries from achieving self-sufficiency in food production. Out of the 328 million ha

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Boron availability in soils and its nutrition of crops under long-term fertility experiments in India

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ABSTRACT

Using 12 long-term (of 15 to 42 years duration) experiments with different cropping systems under various soils and agro-climatic conditions, we studied how different (inorganic and integrated) nutrient management practices influenced boron (B) availability in soils, and its nutrition of nine crops. To this end, four nutrient management practices viz., NPK (recommended dose of N, P and K), NPK + FYM (farmyard manure), control and fallow, which were common in all the experiments, were selected and their effects on B availability in soils were tested using four commonly used methods viz., hot-$CaCl_2$ (HCC), KH_2PO_4 (PDP), mannitol-$CaCl_2$ (MCC) and hydrochloric acid (HCl) in relation to B nutrition of wheat, rice, cowpea, sorghum, sesame, mustard, groundnut, soybean and lentil. Amounts of B extracted by the four different methods followed the order HCC = HCl > MCC > PDP across the tested soils. Averaged over the extractants, long-term nutrient management practices with NPK + FYM resulted in 15% increases in available B in soil over the control, which produced 20% increase in plant tissue B concentration. Such increases with integrated (NPK + FYM) nutrient management practices maintained available B in soils and plant tissues above its critical limits that supplied adequate amounts of B for nutrition of all the tested crops grown intensively for so many years. A B balance study in six experimental sites showed a net B accumulation over time as irrigation water contained and supplied (130–296 g B ha^{-1} $year^{-1}$) more B than removed by harvested crops. Of the four methods used, HCC was the best for assessment of availability of B in soils under long-term cultivation.

1. Introduction

Boron (B) deficiency has been reported in 132 crops from > 80 countries (Shorrocks, 1997). Such deficiency commonly occurs in coarse textured acidic Inceptisols and Entisols, in soils with high amounts of calcium carbonate or Fe- and Al-oxide and hydroxide and

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