

Society for Fertilizers and Environment  
Bidhan Chandra Krishi Viswavidyalaya  
Mohanpur, Nadia,  
West Bengal, India



## From President's Desk



### Reducing carbon footprint is the key to environmental sustainability

Agriculture is the greatest source of living on the planet, and fertilizers are the major means to compensate mining of nutrient reserves in soil due to plant growth. According to FAO, world agriculture is currently responsible for more than half of the atmospheric increase of nitrous oxide ( $N_2O$ ), two-thirds of the global ammonia ( $NH_3$ ) input into the atmosphere, and 40% of global methane ( $CH_4$ ) emissions. These compounds play important roles in atmospheric chemistry, ozone depletion, aerosol formation and greenhouse warming.  $N_2O$  comes from two main sources - livestock manure and chemical fertilizers. In dairy and cattle operations, large amounts of ammonia are produced when urea and livestock manure break down in water or slurry. Since fertilizer is responsible for large amounts of agricultural sector  $N_2O$  emissions, farmers can choose to implement soil management practices that lead to appropriate

fertilizer application rates. In addition to nitrogen field sampling, further  $N_2O$  mitigation options include using cattle feed pads during winter months, using nitrification inhibitors with fertilizer, properly timing fertilizer applications, improving field drainage, and avoiding soil compaction which slows water drainage.

On the other hand, crop-based agriculture occupies 1.7 billion hectares, globally, with a soil C stock of approximately 170 Pg. The oxidation of soil organic matter in cultivated soils is estimated to have contributed approximately 50 Pg C to the atmosphere. Returning the lost soil carbon via increasing C storage in soils is a clear sequestration possibility, and the latter is related to the productivity of crop plants.

The long-term strategy therefore for environmental sustainability through fertilizer use and other interventions under intensive agricultural practices should be by employing such practices that agricultural lands can both sequester carbon and reduce  $CO_2$ ,  $CH_4$ , and  $N_2O$  emissions, thereby reducing their GHG footprint. There could be seven key farming tactics that are proven to be effective in increasing grain production while lowering carbon footprint: (1) using diversified cropping systems can reduce the system's carbon footprint by 32 to 315 % compared with conventional monoculture systems; (2) improving N fertilizer use efficiency can lower the carbon footprints of field crops as N fertilizer applied to these crops might contribute 36 to 52 % of the total emissions; (3) adopting intensified rotation with reduced fallow during summer can lower the carbon footprint by as much as 150 %, compared with a system that has high frequency of summer fallow; (4) enhancing soil carbon sequestration can reduce carbon footprint, as the emissions from crop inputs can be partly offset by carbon conversion from atmospheric  $CO_2$  into plant biomass and ultimately sequestered into the soil; (5) using reduced tillage in combination with crop residue retention, called as conservation agriculture, can increase soil organic carbon and reduce carbon footprints; (6) integrating key cropping practices can increase crop yield by 15 to 59 %, reduce emissions by 25 to 50 %, and lower the carbon footprint of cereal crops by 25 to 34 %; and (7) including  $N_2$ -fixing pulses in rotations can reduce the use of inorganic fertilizer, and lower carbon footprints. With the adoption of these improved farming tactics, one can optimize the systems performance while reducing the carbon footprint of crop cultivation (<https://link.springer.com/article/10.1007/s13593-016-0404-8>).

The present issue of the newsletter deals with impact of nitrogen use on inorganic C stock in soil, activities of beneficial microorganisms to nitrogenous fertilizer application for sustained fertility status, and role of phosphorus in agriculture and environment. In a departure from the trend of use of major nutrients on soil and atmospheric environment role of micronutrients on human and animal health from industrial perspectives has been discussed. Finally, protocol for assessing mitigation potential of GHG emission in terms of C balance in soil tested through large number of village-based trials has been discussed.

HSSen  
President



## NEWS

**National Seminar on “Agri-chemicals for a benign environment”****Date: March 29, 2018****Venue: FACC (Lake Hall), BCKV, Kalyani****Inaugural session**

A National Seminar on “Agri-chemicals for a benign environment” was organized by the Society for Fertilizers and Environment (SFE), Bidhan Chandra Krishi Viswavidyalaya on the occasion of its 5<sup>th</sup> Annual Convention in collaboration with Bidhan Chandra Krishi Viswavidyalaya at Farmers' Academy and Convention Centre (Lake Hall), BCKV, Kalyani on 29 March, 2018. About 200 academicians, scientists, professionals, researchers and students from Universities, Research Institutes, KVKS and Industries participated in the seminar.

The Inaugural session was presided over by the President, SFE, Dr. H.S. Sen. Professor Biswapati Mandal, while welcoming the dignitaries, briefly narrated the origin and activities of the Society and introduced the topic of the national Seminar. The Guest of Honour Dr. D.D. Patra, Vice-Chancellor, BCKV, Mohanpur, in his address, stressed on judicious use of fertilizers commensurate with increasing cropping intensity to feed the growing population. The Chief Guest Swami Atmapriyananda mentioned the importance of ecology and environment and power of environment for the well being of the populace and, therefore, we must protect our environment and ecological balance. Dr. H.S. Sen, while addressing the issues of fertilizers and environment, stated that more research should be carried out on soil microbiological aspects, which is till unexplored in respect of soil health as well as environmental health. The formal vote of thanks was given by Professor Srikanta Das, Organising Secretary of the Seminar.

**Technical sessions***Foundation Lecture*

The 2<sup>nd</sup> Foundation Lecture was chaired by Dr. D.D. Patra, Vice-Chancellor, BCKV and delivered by Professor N. Raghuram, Dean, School of Biotechnology, Guru Gobind Singh Indraprastha University, Delhi on “Indian nitrogen assessment, fertilizer N use efficiency and its improvement”. He explained that environmental accumulation of reactive N compounds such as nitrate, ammonium, nitrogen oxides and particulate N compounds from fossil fuel burning is far beyond the denitrifying capacity of earth. These reactive N compounds cause soil, water and air pollution and climate change. In his talk Professor Raghuram mentioned that unused chemical fertilizers are the biggest source (>60%) of reactive N in India, followed by sewage, vehicular and industrial emissions etc. Over the last decade, N<sub>2</sub>O has replaced methane as the 2<sup>nd</sup> largest greenhouse gas in Indian agriculture. In terms of growth rates, sewage and fossil fuel burning are growing several folds faster than agricultural emissions, indicating the need for multipronged interventions for sustainable development.

Professor Raghuram also mentioned that India and China are fast emerging as global hotspots for reactive N emissions and South Asia is a regional focal point for International Nitrogen Management System, under the UNEP Global Partnership on Nutrient Management (GPNM). India is the first developing country to bring out a comprehensive N assessment for evidence-based national/state/regional policies, as well as for informed international negotiations on various sustainable development goals, especially climate change, health, agriculture, energy, biodiversity and environment. As per the Indian N assessment, fertilizers contribute over 77% of all N<sub>2</sub>O emissions emanating from Indian agricultural soils. Food grain production accounts for up to 70% of all urea consumed in Indian agriculture. Most of it is consumed by rice and wheat. Therefore, enhancement of crop N use efficiency (NUE) and prevention of leakages of N fertilizer from farms is an extremely important area for retardation of climate change. Use efficiency of applied N can be improved in the short term through improved fertilizers and management practices, but crop improvement requires understanding and enhancing the plant's inherent biological capacity to take up, retain, and use the available N.

*Special Lecture I*

Dr. T. Singh, Deputy Manager, IFFCO Headquarters, New Delhi gave a Special Lecture on “Nutrient management for environmental sustainability- IFFCO's initiative” focussing on doubling farmers' income, agricultural infrastructure, agricultural sustainability, climate smart agriculture and crop diversification. While discussing IFFCO's approach on nutrient management he spoke on i) balanced fertilization based on farm research and IPNS, ii) secondary and micronutrients in relation to FAO-FAI, IFFCO-sulphur, phospho-gypsum etc., iii) development of new fertilizers like USG, fortified fertilizer, 100% water soluble fertilizer (WSF) for drip irrigation, iv) agro technologies for sustainable rice-wheat cropping system using SRI and v) promotional programme like field trials starting from 1990s.

*Special Lecture II*

This was delivered by Dr. P.K. Ghosh, National Coordinator, NAHEP-CAAST, New Delhi. He spoke on “Effect of efficient and balanced fertilization on environmental safety”. He emphasized on how to improve the fertilizer use efficiency through agronomic management and to protect soil C storage and thereon the need of second green revolution.

*Special Lecture III*

Dr. Swami Reddy, Director, ICAR-CRIDA, Hyderabad delivered a special lecture on “Assessing the mitigation potential of greenhouse gas emissions in terms of C balance in climatically vulnerable villages of Gujarat, Rajasthan, Andhra Pradesh and Maharashtra states of India using EX-ACT tool”. The lecture note is given afterwards in this issue.

*Poster Presentation*

Total 79 posters were presented by the scientists, teachers, researchers and students of different disciplines. All these posters were

critically judged by a committee comprised of i) Dr.DilipKundu, Principal Scientist, ICAR-CRIJAF, Barrackpur, ii) Dr.Dhiman Barman, Principal Scientist, ICAR-CSSRI, RRS, Canning Town and iii) Professor Krishna Karmakar, BCKV, and the following three posters were adjudged as the best posters,

**1<sup>st</sup> position:**

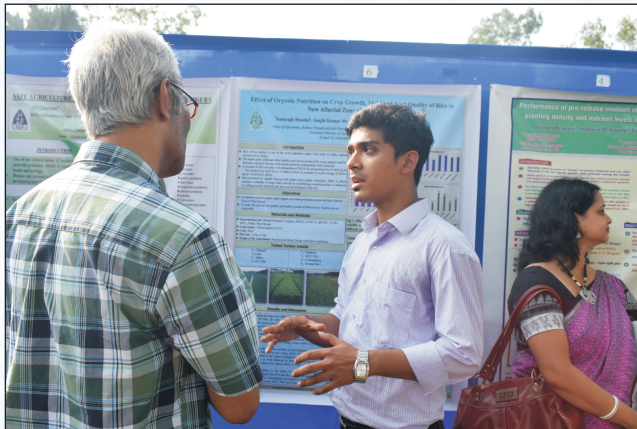
“Better together: plant growth promoting microbial consortium for acid soils” by Anand Kumar Naorem and DwipendraThakuria

**2<sup>nd</sup> position:**

“Development of a multiresidue method of 86 multiclass pesticides by GC-MS/MS for pineapple export” by Sushovan Das, AbhishekKundu, DebasishSingha, SumanSaha, SattikiGhosh and Sankhajit Roy

**3<sup>rd</sup> position:**

“Management of root knot nematode (*Meloidogyne incognita*) race 2 in cowpea through bio-agents - a way to replace the chemical nematicide application” by A Kar, S Mondal (Ghosh) and G Chakraborty



## MEETINGS

### Executive Committee Meeting 1

**Venue:** ICAR-ATARI, BhumiVihar Complex, Block GB, Sector III, Kolkata 700 097

**Date:** 22.02.2018

The meeting was chaired by President, SFE in presence of following members. Decisions of the meeting are given below,

1. Dr. H.S. Sen, President
2. Prof. B. Mandal, Secretary
3. Dr. D.C. Nayek, Vice-President
4. Dr. F.H. Rahman, Joint-Secretary
5. Dr. D. Sarkar, Treasurer
6. Dr. D. Ghorai, Member
  - The proceedings of the EC meeting held on 03 August, 2017 at the ICAR-ATARI were accepted unanimously and confirmed in the meeting.
  - Organising a one day National Seminar cum AGM in 29/30 March, 2018.
  - A proposal will be given to Dr. A.K. Singh, Vice-Chancellor, BAU, Sabour for organising a National Seminar at Bihar Agricultural University, Sabour
  - One sensitization programme to be conducted for students at Durgapur College.
  - Possibilities of sponsorship for the Newsletter from Industry and ICAR is to be explored.
  - Rs. 3.0 lakh out of the bank balance of 4.2 Lakh will be invested in the form of FD.

### Executive Committee Meeting 2

**Venue:** Farmers' Academy and Convention Centre (Lake Hall), BCKV, Kalyani

**Date:** 29.03.2018

The meeting was chaired by President, SFE in presence of following members. Decisions of the meeting are given below.

1. Dr. H.S. Sen, President
2. Prof. B. Mandal, Secretary



3. Dr. D.C. Nayak, Vice-President
4. Dr. F.H. Rahman, Joint-Secretary
5. Dr. D. Sarkar, Treasurer
6. Dr. D. Ghorai, Member
7. Dr. A.R. Saha, Member
8. Dr. Kanu Murmu, Member
9. Dr. Snigdha Chandra, Member
10. Dr. Siladitya Bandyopadhyay, Member

- The proceedings of the EC meeting held on 22 February, 2018 at the ICAR-ATARI were briefly narrated by the Secretary, accepted unanimously and confirmed in the meeting.
  - Decision of Secretary, SFE to publish Souvenir for National Seminar in soft form instead of conventional hard form was unanimously accepted by the members.
  - The house agreed upon Dr. Kanu Murmu, Dr. Snigdha Chandra and Dr. Siladitya Bandyopadhyay induction in the Editorial Board of the Newsletter
  - The EC to be expanded with inclusion of following members,
    - i) Dr. N.C. Sahu
    - ii) Dr. Krishnendu Das
    - iii) Dr. Dhiman Barman
    - iv) Prof. S. Mallick
    - v) Dr. Kaushik Batabyal
    - vi) Dr. Sidhu Murmu
- \* Proposed activities for the coming year to include,
- i) An interaction meeting of Researchers and Industry Personnel.
  - ii) Awareness programme for students/farmers
  - iii) Follow-up programmes in Sargachi, and Goshaba

### Executive Committee Meeting 3

**Venue:** Directorate of Research, BCKV, Kalyani

**Date:** 08.05.2018

The meeting was chaired by President, SFE in presence of following members. Decisions of the meeting are given below.

1. Dr. H.S. Sen, President
2. Prof. B. Mandal, Secretary
3. Prof. Kunal Ghosh, Ex-President
4. Dr. D.C. Nayak, Vice-President
5. Dr. F.H. Rahman, Joint-Secretary
6. Dr. D. Sarkar, Treasurer
7. Prof. G.C. Hazra, Member
8. Prof. Surajit Mallick, Member
9. Dr. D. Ghorai, Member
10. Dr. A.R. Saha, Member
11. Dr. Sidhu Murmu, Member
12. Dr. Kaushik Batabyal

The proceedings of the EC meeting held on March 29, 2018 at the FACC, BCKV, Kalyani were briefly narrated by the Secretary, accepted unanimously and confirmed in the meeting.

- Dr. Sen advised to make National and International Bank of Authors for continuous supply of quality articles for Newsletter.
- The society is to be registered with ICAR/other government departments for ensuring regular flow of funds for basic activities. The secretary would discuss the matter with ADG (SWM) or ADG (Coordination) or similar authority during his visit to New Delhi. Also, the Society is to be registered with NitiAyog through NGO Darpan website and PFMC as pre-requisites to approach ICAR.
- The proposed activities for the coming year to include,
  - I. An interaction meeting of Researchers and Industry Personnel.
  - II. Awareness programme for students/farmers in the Govt. College of Durgapur by September/October 2018.
  - III. Follow-up programmes in Sargachi and Goshaba
- Rs. 3.0 lakh of deposited money in the Savings account will be invested in short-term Fixed Deposit. The unit of Fixed Deposit will be of Rs. 50,000 in annual auto renewal mode where, the annual interest will move to the Savings account.
- Formalities for change of official address of the Society from Kolkata to Bidhan Chandra Krishi Viswavidyalaya will be done.
- IT return of the Society will be submitted regularly.



## Annual General Meeting

Venue: FACC, BCKV, Kalyani

Date: 29 March, 2018

The Annual General Meeting (AGM, for 2017-18) was participated by fifty seven members and was chaired by Dr. H.S. Sen, President of SFE. Prof. Biswapati Mandal, Secretary of the Society presented the agenda listed. After thorough deliberations and discussion following resolutions are taken.

### 1. Selection of patrons/Fellows

Detail guidelines, procedure and format for nomination were presented. Members suggested only some minor corrections in the proforma before uploading it in the Website of SFE. Further change in the selection criteria, if required, will be deliberated upon and endorsed in the next AGM. Question raised as to the number of patrons for the Society. It was decided that if situation so arise that number of patrons are to be increased over three, it will be done through deliberations in the AGM only.

### 2. Newsletter

Dr. Sen, invited suggestions for improving the Newsletter. Members suggested for inclusion of ISB number for the Newsletter, which will be useful for getting monetary support from ICAR etc. The President of the Society will explore the possibility for getting funds from ICAR for the Newsletter. Both the President and Secretary expressed their concern about getting quality articles in time for publication in the Newsletter. Each member of the Society were requested to give a note of not more than one page stating what to be published in the Newsletter and the members were also requested for their contribution by giving relevant articles for the Newsletter. The inclusion of the following members in the Editorial Committee of the Newsletter, which was decided in the previous Executive Committee meeting, was endorsed.

- i) Dr. Kanu Murmu
- ii) Dr. Snigdha Chandra
- iii) Dr. Siladitya Bandyopadhyay

### 3. Expansion of EC

The proposal for expansion of the existing Executive Committee with inclusion of the following members of the Society was endorsed.

- i) Prof. S. Mallick
- ii) Dr. N.C. Sahu
- iii) Dr. Krishnendu Das
- iv) Dr. Dhiman Barman
- v) Dr. Kaushik Batabyal
- vi) Dr. Sidhu Murmu

The Composition of the expanded Executive Committee of the Society is given below:

1. President: Dr. H.S. Sen
2. Vice-President: Dr. D.C. Nayak
3. Secretary: Prof. Biswapati Mandal
4. Joint Secretary: Dr. F.H. Rahman
5. Treasurer: Dr. Dibyendu Sarkar
6. Other Council Members:  
Dr. G.C. Hazra, Dr. D.K. Kundu, Dr. Dipankar Ghorai, Dr. S. Bhadra Roy, Dr. Amit Rastogi, Dr. Pradip Dey, Dr. Kanu Murmu, Dr. S. Chandra, Dr. S.K. Roy, Dr. A.R. Saha, Prof. S. Mallick, Dr. N.C. Sahu, Dr. Krishnendu Das, Dr. Dhiman Barman, Dr. Kaushik Batabyal, Dr. Sidhu Murmu

### 4. Financial status

Dr. Dibyendu Sarkar, Treasurer of the Society presented the audit report of SFE for the financial year 2016-2017 and it was accepted in the meeting. He reported that the Society is having about Rs. 4.2 lakh bank balance as on 29 March, 2018. Dr. Sarkar also mentioned that the cost of organising the 5<sup>th</sup> Annual Convention cum National Seminar could be met from the sponsorship by the Industries and a collection of about Rs. 90,000 from Registration could be saved for the Society. In the meeting it was also decided that Rs. 3.0 lakh of SFE would be invested in short-term Fixed Deposit.

### 5. Proposed activities for the coming year

The AGM decided that the following programmes would be undertaken in the coming year of 2018-19.

- i) An interaction meeting of Researchers and Industry Personnel;
- ii) Awareness programme for students/farmers in Durgapur College;
- iii) Follow-up programmes in Sargachi, Murshidabad and Sundarban area of North-24 Parganas.

### 6. Miscellaneous items

- i) Registration of SFE should be renewed regularly
- ii) Address change of SFE should officially be done with the help of a Lawyer.
- iii) UDI registration will be made with the help of Dr. Dhiman Barman

The meeting ended with formal vote of thanks given by Dr. F.H. Rahman, Joint Secretary of SFE.

**ARTICLES****ARTICLE - 1****Phosphorus: A critical element for agriculture and environment**

Phosphorus is an essential element for crop production; however it may also have detrimental effects on water quality. Limited phosphorus reserves exist only at the earth's crust in the form of phosphate rock. The natural phosphorus flow occurs very slowly (can take place over 1 million years), remains relatively constant in quantity, and contributes to a stable closed loop. The situation has however been significantly changed by human activities, particularly since industrialization, which has resulted in some serious environmental problems that modern societies face today. Phosphate rock is initially converted to phosphoric acid by reaction with sulphuric acid. The phosphoric acid is further processed to produce fertilizers, food-grade and feed-grade additives, and detergents (Liu *et al.*, 2008). Globally, approximately 90% of all phosphate demand is used for the production of agricultural fertilizer (82%) during food production primarily and a smaller fraction for animal feed additions (7%) and food additives (1-2%). The remaining 9% goes to industrial uses such as for production of detergents and metal treatment, etc. (Prud'homme, 2010).

***Phosphorus role in Indian agriculture***

Introduction of modern high yielding varieties and development of irrigation facilities during 1960s caused a huge increase in consumption of chemical fertilizer in India. With the increased use of total nutrient in exploitive agriculture, the proportion of phosphatic fertilizer has also been increased. Over a few decades, phosphate use in India (totally dependent on import) has been doubled in quantity (80% increase between 2002 and 2009) (FAO STAT, 2012). Further, with increase in population growth, changes towards meat-rich diets and growing demands for food production will push an increasing demand for phosphate in the near future.

***Phosphorus status in soil***

Phosphorus is often the main constraint for plant growth in highly weathered soils of the tropics. Continuous supply of P through manures and fertilizers is indispensable for crop production. Generally, P is applied as pre-plant incorporation (before planting/sowing) in soil for many agricultural crops. Not all the P applied to soil is absorbed by the crops. The P uptake efficiency is mostly around 10-30% (average 20%) in most agricultural soils and the remaining P fixed in the soil. Under intensively cultivated areas of India, continuous addition of fertilizer and manure in excess to crop requirement will result an increase in phosphorus content in the surface soil.

Results of a long-term field experiment carried out in Punjab showed that 25 years of annual application of P fertilizers caused an increase in Olsen P status in the plough layer (0-15cm) of soil (Aulakh *et al.*, 2007). It also reported that 43-58% Olsen P was below 60cm depth indicating enormous movement of applied P to deep layers in coarse textured soils with low P retention capacity for nutrients. At present 5% of the Indian soils have adequate available P, 49.3% are under low category, 48.8% under medium, and 1.9% under high category (Pattanayak *et al.*, 2009). Phosphorus in soils is almost entirely associated with soil particles (particle associated P). Only very little P is present in soil solution, its concentration being less than 0.1 mg P/l. When soil erosion occurs, soil particles are removed which eventually reaches fresh water bodies and ocean through wind and water agents causing eutrophication. Research results have shown that soils testing high in P have a greater contribution effect for P loss than soils testing low in P. While good agronomic management requires use of fertilizer P to optimize crop growth, excessive application of P may degrade water quality. Thus phosphorus plays key role in sustainable crop production as well as environmental quality.

***Eutrophication and potential source***

Eutrophication is the natural aging of lakes or streams brought on by nutrient enrichment, greatly accelerated by human activities. While nitrogen, phosphorus, carbon, and in some cases, silicon contribute to



eutrophication, P is the primary agent in freshwater eutrophication, as several algal species are able to obtain N from the atmosphere (Schindler, 1977). Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease oxygen that fish and other aquatic life need to survive leading to the death of large number of fishes. The natural levels of phosphate in the aquatic ecosystems usually range between 0.005 to 0.05 mg l<sup>-1</sup>. In many countries the threshold level of P is 0.03 to 0.1 mg l<sup>-1</sup> above which the aquatic bodies are vulnerable for algal blooms. Several studies in India indicated that the total P in surface water bodies was very high and exceeded the threshold value of 0.1 mg l<sup>-1</sup> (Dixit *et al.*, 2005). The main sources of phosphate in aquatic environment are household sewage water containing residues of detergents and cleaning preparations, agricultural runoff containing fertilizers as well as industrial effluents from fertilizer, detergent and soap industries. The relative contribution from different sources may vary on regional and local scales depending upon the degree of urbanization, sewage management and intensity of agricultural practices. If human induced global environmental impacts continued as in the past, nearly 2.4 and 2.7 fold increases in nitrogen- and phosphorus driven eutrophication of terrestrial, freshwater and near-shore marine ecosystems will occur (Tilman *et al.*, 2001).

#### **Phosphorus loss from agricultural fields**

Phosphorus is considered to be immobile in soil and highly mobile in plant system. The transport of P in agriculture field can occur by surface runoff and subsurface flow. It depends upon the soil type, rate of P application, source of P, amount and intensity of rainfall, and soil P status. Phosphorus enters into water bodies either as dissolved or particulate forms. During periods of heavy rainfall, water flowing over the soil surface carries eroded soil particles containing P (sediment P/ particulate P). Recently applied fertilizer or manure in the soil is the large source of dissolved P into the water bodies. When the rainfall is less intense, it percolates into the soil and the excess leaches downwards carrying soluble substances with it (Sims and Kleinman, 2005). Majority of P leaked into the environment, enters natural water in non-bio-available form, bound to particulate matter (from runoff and erosion), while only 5–10% occurs in soluble/dissolved form. Phosphorus fractions (Table 1) in the water samples of Upper Lake, Bhopal revealed that 66.8% of the total P (0.37 mg l<sup>-1</sup>) was in particulate form (more than 450 nm particles) and remaining 33.3% was in ionic and dissolved form (less than 450 nm particles) (SubbaRao *et al.*, 2011; Kundu *et al.*, 2015). Also many reports from western countries have shown that about 70 to 90% of P from croplands associated with eroded soil was lost as particulate form. The sediment attached P contributes to long-term P additions to the system whereas the dissolved P is readily available for assimilation by aquatic plants and algae.

#### **Soil test to predict P losses**

The existing soil P test methods like Olsen, Mehlich 3, Bray, acetic acid, etc are designed to measure available P and to identify yield responsive of soils. But it gives no indication of the potential for transport of P to predict environmental P losses. This is because rainfall, erosion potential, drainage, distance from the receiving watercourse, and management factors can also affect the likelihood of P being lost from agricultural fields. As soil test alone cannot predict P transport, various indicators of P have been proposed in different regions in the US and European countries as tools to efficiently assess the risk of P pollution. The P index and degree of P saturation (DPS) concept was developed and successfully used globally as a valuable nutrient management tool to predict the risk of P loss from agricultural fields (Rashmi *et al.*, 2015).

#### **Minimizing P loss from agriculture and restoration of fresh water bodies**

To manage, monitor and regulate P flows in earth system by industry, agriculture, and livestock/human, and ultimately checking the flows to ocean system /fresh water bodies, it is necessary to design site specific P management strategies at national and regional level. There are several measures available to minimize P loss in agricultural runoff considering its sources and transport mechanisms. However, the overall goal of efforts to reduce P loss to waterbodies should be to balance P inputs and outputs at farm and watershed levels, while managing soil P in ways that maintain productivity. Management strategies that minimize P loss to water may involve optimizing P use efficiency, refining animal feed rations, using feed additives to increase animal absorption of P, moving manure from surplus to deficit areas, and applying conservation practices,



such as reduced tillage, buffer strips, and cover crops (Shigaki *et al.*, 2006). To conclude, efficient use of P resources for crop production are of paramount importance in the sphere of fast depleting P reserves and environmental problems like eutrophication. Therefore, to achieve both economic and environmental safeguard it is important to develop a P management plan to utilize the available P resources efficiently in the country.

**Table 1. Different phosphorus fractions (mg/l) in water samples (various locations) of Upper Lake, Bhopal (mean value of data collected during 2012- 2013)**

	Total P	% of Total P				
		Total dissolved P	Total reactive P	Dissolved reactive P	Dissolved organic P	Particulate P
Range	0.32 - 0.43	22.54 - 38.62	14.61 - 22.08	6.91 - 14.07	3.37- 19.52	52.63 - 75.94
Mean	0.372	33.19	17.54	8.99	17.61	66.81
STDEV	±0.0357	±0.0166	±0.0224	±0.0407	±0.0198	±0.0514

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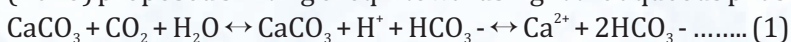
## ARTICLE - 2

### Nitrogen and its impact on inorganic C- stocks in soil environment

N application through fertilizers, such as urea, ammonium sulphate, etc. to crops is inevitable for improving crop productivity and feed the increasing population at global and national scale. On an average, 2500 Pg C is stored in soils of 1.0 m depth, while about 1550 Pg (62%) and 950 Pg (38%) are organic and inorganic sources, respectively. The soil C pool is 3.3 times higher than the atmospheric pool (760 Pg) and 4.5 times that of biotic pool (560 Pg). Recently the higher concentration of atmospheric CO<sub>2</sub> concentration above 400 ppm ([www.co2.earth](http://www.co2.earth)) has drawn attention and is considered a serious concern. Any change in soil C further affects the atmospheric CO<sub>2</sub> concentration, and participates in global warming. CO<sub>2</sub> exchange between soil and atmosphere is controlled by the decomposition rate of soil organic matter as influenced by management practices such as tillage and fertilization. Fertilizer type, rate of application, and crops/crop rotations under varied agroclimatic regions are important factors affecting CO<sub>2</sub> efflux from soil. The quality and quantity of soil organic carbon varies in a wide range of climates such as arid, semiarid, humid and tropical and is largely controlled by the soil and water management practices of the region.

#### *CaCO<sub>3</sub> as inorganic carbon source in soil*

Inorganic carbon is commonly present as CaCO<sub>3</sub>, a significant content of which is present in calcareous soils normally distributed in arid and semiarid regions (Eswaran *et al.*, 2000). Due to immobilization of CO<sub>2</sub> in soil, the role of CaCO<sub>3</sub> on CO<sub>2</sub> efflux is almost negligible. Redistribution of CO<sub>2</sub> as CaCO<sub>3</sub> had resulted in its deficiency at surface and sub-surface root zones of the calcareous soils in arid and semiarid regions (Zamanian *et al.*, 2016). Thus, soil inorganic carbon (SIC) has influence on soil chemical degradations in absence of arable cropping. Deep-rooted crops such as horticultural and forestry plantations are potentially resistant to CO<sub>2</sub> efflux originated from CaCO<sub>3</sub> dissolution in presence of weak acids such as, H<sub>2</sub>CO<sub>3</sub> produced during roots and microbial respiration (eq.1). Such acids essentially improve the low solubility (0.013 g/L in H<sub>2</sub>O at 25°C) of CaCO<sub>3</sub> in soils and produce about 0.3 g/L of CO<sub>2</sub> (Zamanian *et al.*, 2018). Thus, Monger *et al.* (2015) proposed shifting of eq.1 towards right the aqueous phase of HCO<sub>3</sub><sup>-</sup>.



Rice and Herman (2012) also reported an increase in the CaCO<sub>3</sub> dissolution rate following application of organic (FYM) and mineral nitrogenous (N) fertilizer, such as urea. Bolan *et al.* (1991) clarified the urease produced during microbial transformation participates in the hydrolysis of urea to produce ammonium while nitrifying bacteria oxidizes ammonium to nitrate, releasing acids as H<sup>+</sup>. In poorly drained soils, the uptake of NH<sub>4</sub><sup>+</sup> by roots in exchange of H<sup>+</sup> leads to soil acidity. Such acidity participates in CaCO<sub>3</sub> dissolution in calcareous soils, characterized by alkaline reaction with poor internal drainage and physical properties along with seasonal waterlogging of soil profiles (Huang *et al.*, 2015). Chen *et al.* (2013) also corroborates such observation and suggest as the primary processes of dissolution of CaCO<sub>3</sub> during anthropogenic acidity that led to CO<sub>2</sub> efflux and Ca<sup>2+</sup> release in soil profile (Chmiel *et al.*, 2016). Conyers *et al.* (1996) reported an interesting result that showed the rate of dissolution @ 46–95 kg CaCO<sub>3</sub> ha<sup>-1</sup> year<sup>-1</sup> in arable crops fertilized with 100 kg urea-N ha<sup>-1</sup> year<sup>-1</sup> for 12 continuous years. Huang *et al.* (2015) reviewed the impact of N fertilization on the changes of inorganic C stocks in soil, status of CO<sub>2</sub> efflux to the atmosphere that apparently controls soil C balance and global warming.

#### *CO<sub>2</sub> efflux from soil*

Following N fertilization the rate of soil CO<sub>2</sub> efflux was @ 7.48 × 10<sup>12</sup> g C/year due to CaCO<sub>3</sub> dissolution (Table 1) (Zamanian *et al.*, 2018). The prominent areas showing the CO<sub>2</sub> efflux from N fertilization are central USA, northern France and the Iberian Peninsula, eastern China and northern India (along the Ganges River), and Egypt (along the Nile River).

**Table 1. The contribution of CaCO<sub>3</sub> dissolution to CO<sub>2</sub> efflux from soil**

Applied N (kg N ha <sup>-1</sup> year <sup>-1</sup> )	Surface area (10 <sup>9</sup> ha)	CO <sub>2</sub> efflux (10 <sup>12</sup> g C/year)
0.44	2.85	0.26
1.74	0.61	0.21
3.9	0.42	0.33
7.8	0.35	0.56
14.7	0.32	0.95
27.3	0.28	1.44
128	0.26	3.73

(Adopted from Zamanian *et al.*, 2018)

FAO (2015) reported the N fertilization would be  $11.9 \times 10^{10}$  kg N during 2018, which is much higher than the average reported in 2010 (Zamanian *et al.*, 2018). Assuming an equal increase in N fertilization worldwide, the predicted CO<sub>2</sub> efflux from SIC due to N fertilization will be  $12.7 \times 10^{12}$  g C/year ( $46.6 \times 10^{12}$  g CO<sub>2</sub>/year) (Zamanian *et al.*, 2018), which is a serious issue for arable cropping and maintaining sustainable soil environment.

#### ***N* fertilization-induced acidity, dissolution of CaCO<sub>3</sub>, and suggested impact on environment**

At global level, about  $2.04 \times 10^9$  ha is reported under risk due to N fertilization-induced acidity (Zamanian *et al.*, 2018). An estimate reported by Vries and Breeuwsma (1987) showed the acidity produced by N fertilization is as high as 25 times of that induced by acid rain, that caused decline of soil pH by 0.13–0.8 units (Mahler *et al.*, 2016) or the average rate of decline of soil pH @ 0.03 unit per year reported by Conyers *et al.* (1996). The fact is that acidity produced due to N fertilization is localized and restricted to surface layers and, as a result, the CaCO<sub>3</sub> layers at lower soil depth remain unaffected (Datta and Mandal, 2018). Soils rich in clays and organic carbon do not report any significant changes on acidity apparently due to higher buffering capacity. On the other hand, changes in soil pH from organic acids produced by organic matter decomposition and concomitant dissolution of immobilized/precipitated CaCO<sub>3</sub> and its leaching was a rare possibility in Vertisols (Pal *et al.*, 2012). Currently, experiments on conservation agriculture showed some indications of acidity due to sequestration and decomposition of SOC (Powlson *et al.*, 2014). In-depth studies at laboratory and field scale are thus necessary to establish dissolution of CaCO<sub>3</sub> due to N fertilization under different management practices. Management of N fertilizer application should be taken on priority to prevent soil degradations due to acidity, reduce CO<sub>2</sub> losses, and avoid harmful impacts on soil health and environmental safety.

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### ARTICLE - 3

#### Response of some beneficial soil microorganisms to application of nitrogenous fertilizers in new alluvial soils of West Bengal

Since addition of chemical fertilizer directly influences the soil microbial community, proper appreciation of ecosystem functioning, the biological condition of soil ecosystem must be studied to evaluate the microbial status of the soil. Traditionally, response to any changes at the microbial scale has been studied by evaluating the population, respiration rates (Nanniperi *et al.*, 1990) and enzyme activities (Perucci *et al.*, 2000). In recent years, indicative components like soil microbial biomass carbon (MBC), community structures, functions, and enzyme activities have been used to describe soil qualities under different agricultural practices.

#### Methodology used

In this backdrop, a study was conducted to evaluate the effect of application of different nitrogenous fertilizers on the population and activities of some beneficial soil microorganisms in two new alluvial soils (Arampur and Mandouri) of two districts viz., South 24 Parganas and Nadia, respectively of West Bengal. The soils (0-15cm) were collected at field moist condition and stored for 7 days for stabilization of the system at 60% WHC of the soils, and incubated with the fertilizers as per doses for 60 days at ambient temperature. Different nitrogenous fertilizers (urea, calcium nitrate and ammonium sulphate) with varying doses (0, 30, 60 and 90 kg ha<sup>-1</sup>) were applied to soils as per followings: T<sub>1</sub>: Control; T<sub>2</sub>: Urea @ 30 kg ha<sup>-1</sup>; T<sub>3</sub>: Urea @ 60 kg ha<sup>-1</sup>; T<sub>4</sub>: Urea @ 90 kg ha<sup>-1</sup>; T<sub>5</sub>: Calcium nitrate @ 30 kg ha<sup>-1</sup>; T<sub>6</sub>: Calcium nitrate @ 60 kg ha<sup>-1</sup>; T<sub>7</sub>: Calcium nitrate @ 90 kg ha<sup>-1</sup>; T<sub>8</sub>: Ammonium Sulphate @ 30 kg ha<sup>-1</sup>; T<sub>9</sub>: Ammonium Sulphate @ 60 kg ha<sup>-1</sup>; T<sub>10</sub>: Ammonium Sulphate @ 90 kg ha<sup>-1</sup>. The soil samples were taken on 0, 7, 15, 30, 45 and 60 days of fertilizer application and different parameters were measured as per the standard procedures. The physicochemical properties of the soils are given in Table 1. The monitoring of the microbial response was done by evaluating the microbial population viz., *Azotobacter* sp., *Rhizobium* sp., phosphate solubilizing bacteria (*Pseudomonas* and *Bacillus* sp.), as well as basal soil respiration (BSR) as indicators of microbial activity.

**Table 1. Physicochemical properties of two different soils**

Parameters	Soil 1 (Arampur, South 24 Parganas)	Soil 2 (Mandouri, Nadia)
Water holding capacity (%)	53	54.04
pH	7.22	6.20
ECe (dS/m)	0.19	0.03
OC (%)	0.62	0.48
P2O5( kg ha <sup>-1</sup> )	79.04	56.92
K2O( kg ha <sup>-1</sup> )	926	642

### Response of microbial activities

Interestingly, it was found that the ammonium sulphate and calcium nitrate favoured the microbial population and respiration activity as compared to urea. As observed from the findings, the population of phosphate solubilizing bacteria (*Pseudomonas sp.* and *Bacillus sp.*) in both the soils increased with progress of time. Highest number of CFU of *Pseudomonas sp.* was found in both the soils in the treatment receiving calcium nitrate @ 30 kg ha<sup>-1</sup> and highest CFU of *Bacillus sp.* was obtained in treatment receiving ammonium sulphate @ 30 kg ha<sup>-1</sup> i.e., both at the lower doses of fertilizer treatment (Fig.1). It indicated that higher dose of fertilizer (@ 90 kg ha<sup>-1</sup>) might exert an adverse effect on the population of the microorganisms in both the soils. The results were well corroborated by the findings of New *et al.* (2013) where phosphate solubilizing activity by the bacterial population was affected by the higher doses of salt concentration sourced from the fertilizer application. In case of *Rhizobium sp.*, highest CFU counts were obtained in both soils in the treatment of calcium nitrate at lower dose i.e., @ 30kg ha<sup>-1</sup> and highest population of *Azotobacter sp.* was obtained in the treatment of ammonium sulphate @ 30kg ha<sup>-1</sup> in both the soils (Fig. 1). The findings suggested that the application of nitrogenous fertilizers at lower doses significantly stimulated the free-living nitrogen fixing bacteria and *Rhizobium sp.* population in comparison to other treatments. It was found that fertilizer stimulates microbial growth up to a certain level and may affect the composition of individual microbial communities.

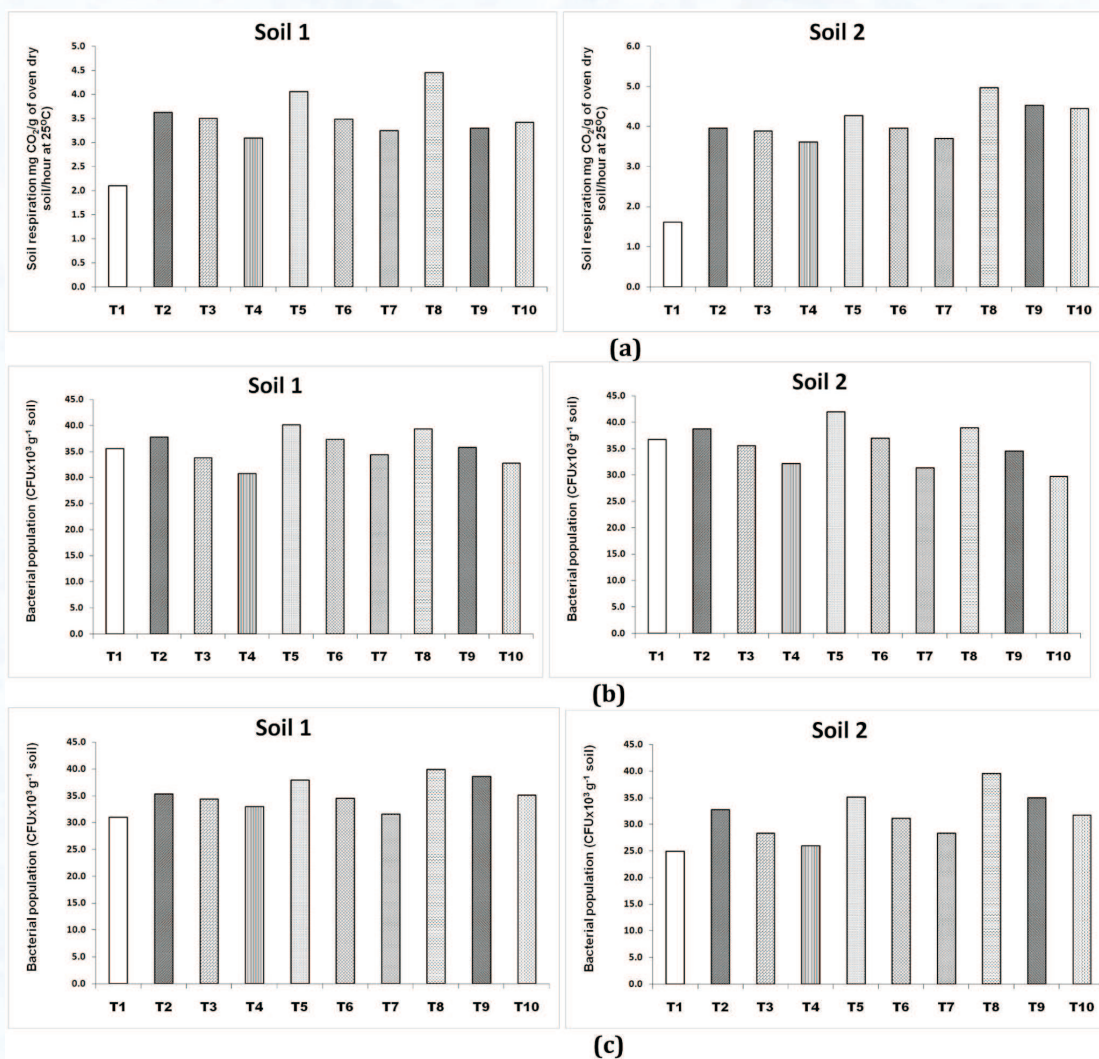
The activity of biological processes in soil is reflected by the amount of carbon dioxide exuded from the soil i.e., soil respiration, which indicates the microbial activity of the soil (Nanniperi *et al.*, 1990). Carbon dioxide (CO<sub>2</sub>) is exuded because of disintegration of organic matter of plant and animal origin in the soil, plant roots, breathing, etc. Inorganic fertilizers are primarily used to increase nutrient availability to plants, but they can also affect soil microorganisms (Marschner *et al.*, 2003). The application of nitrogenous fertilizers significantly increased the microbial respiration in both the soils as compared to the control (Fig. 1). Increasing population of the community resulted from the addition of fertilizers in soil which generally stimulates the microbial ecosystem or nutrients derived from the fertilizers itself and acted as the food source to the growing microbial community with increasing CO<sub>2</sub> evolution. Zakarauskaitė *et al.* (2008) also found the same trend where application of NPK fertilizers significantly increased the microbial respiration of soil as compared to the soil without fertilizers application. However, respiration rate decreased as the dose of nitrogenous fertilizer increased i.e., higher rate of fertilizer suppressed the microbial activity. The findings were in agreement with the findings of Thirukkumaran and Parkinson (2000). Increase in microbial respiration due to increase in the days of incubation may be attributed to less availability of easily decomposable organic matter during the initial period of the study, and larger availability of easily decomposable organic matter in the later phase of the study, oxidation of which liberated larger amount of CO<sub>2</sub> through microbial respiration. The study indicated a strong positive correlation between the CFU counts and BSR.

Both the soils under study were C-poor, particularly in N-limited ecosystems and the application of nitrogenous fertilizers at lower doses increased the microbial respiration rate, which is consistent with other

studies (Yuchun *et al.*, 2014). These responses may have occurred because high levels of N addition can shift an ecosystem from N limitation to N saturation, which should negatively affect soil respiration (Jiangming *et al.*, 2008). Thus, the effects of N addition on soil respiration appeared to depend on nutrient limitation and the rate of N addition. Most studies examining the effect of N fertilizer on soil microbial respiration found that N applications at higher doses can reduce respiration rates (Ramirez *et al.*, 2012). The result of this study indicated that the respiration rate of microbes in C-poor soil might have been limited by exogenous soil N. For C-poor soil, it is possible that the input of exogenous N enhanced the activity of soil microbes limited by N nutrition accelerating the decomposition of soil organic matter (Neff *et al.*, 2002). In addition, the negative effects of high dose of N on soil microbial respiration might be due to the reduction of soil pH following N addition, thus inhibiting soil microbial activity (Ramirez *et al.*, 2012).

### Concluding remarks on microbial activities vis-à-vis fertilizer application

To keep the soil as a biological living system and to maintain proper functioning capacity of soil, it is very much necessary to give the proper importance on the soil biological ecosystem. Because it is as simple as that the liveliness of the soil biological ecosystem will ensure all the nutritional requirement to the plant when fertilization to the soil will be maintained as per requirement. Thus, it may be concluded that the excess application of chemical fertilizer may improve the soil nutrient availability, but the soil microbial ecosystem might be affected leading to the soil health degradation on long term basis. The application of chemical fertilizer in recommended doses as per requirement depending on the soil test report should be aimed at improving the soil microbial population and the microbial activities, in addition to nutrient status per se, to ultimately maintain the soil fertility in a sustainable manner.



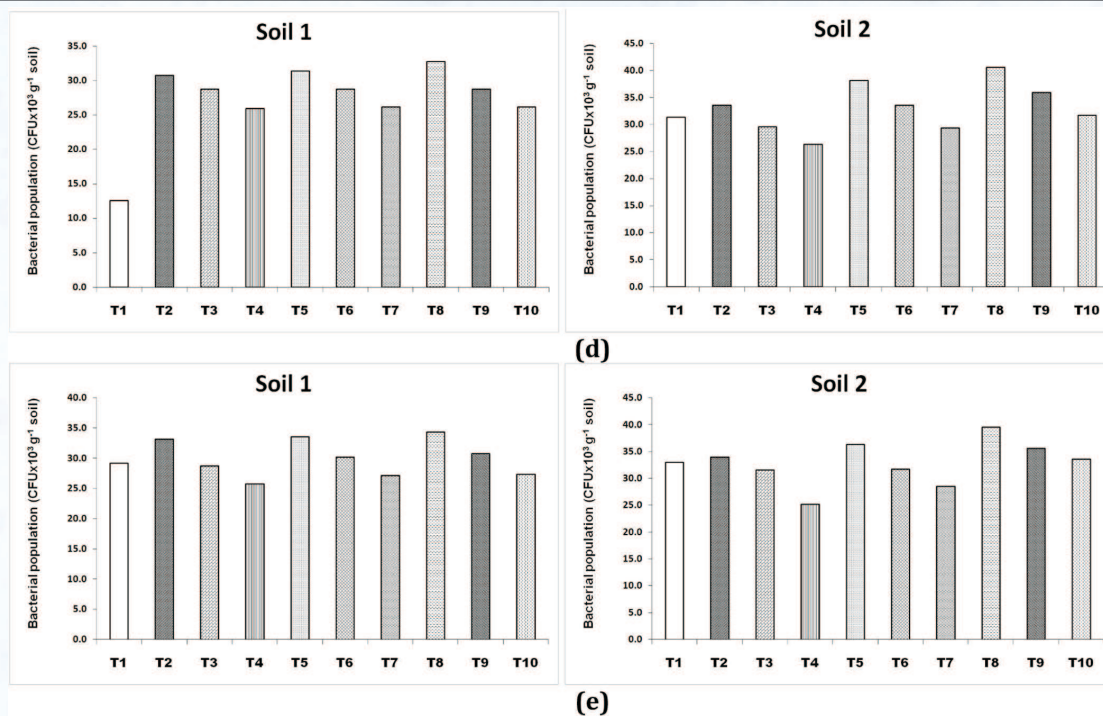


Fig. 1. Changes in soil microbial activity parameters due to fertilizer treatments in two soils viz., Soil 1: Arampur, Gosaba, South 24-parganas; Soil 2: Mandouri, Haringhata, Nadia. Fertilizer treatments: T2-T4 Urea, T5-T7 Calcium nitrate, T9-T10 ammonium sulphate; T2, T5, T8 30 kg ha<sup>-1</sup>, T3, T6, T9 60 kg ha<sup>-1</sup>, T4, T7, T10 90 kg ha<sup>-1</sup>. Microbial parameter: (a) Basal soil Respiration Rate, (b) *Pseudomonas* spp. Population, (c) *Bacillus* spp. Population, (d) *Rhizobium* spp. Population, (e) *Azotobacter* spp. Population

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#### ARTICLE - 4

### Impact of fertilizers with special reference to micronutrients on environment pertaining to human and animal health

Fertilizers are an indispensable agri-input and are added to aid and increase the supply of essential nutrients required for growth and development of plants. There are 16 nutrient elements required to grow crops. Three essential nutrients - carbon (C), hydrogen (H), and oxygen (O<sub>2</sub>) - are taken up from atmospheric carbon dioxide and water. The other 13 nutrients are taken up from the soil and are usually grouped as primary nutrients, secondary nutrients, and micronutrients. The primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). Primary nutrients are utilized in the largest amounts by crops, and therefore, are applied at higher rates than secondary nutrients and micronutrients. The secondary nutrients - calcium (Ca), magnesium (Mg), and sulphur (S) - are required in smaller amounts than the primary nutrients, although there are opinions that S may be a major nutrient in some cases. Micronutrients - iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), and molybdenum (Mo), selenium (Se) - are required in even smaller amounts than secondary nutrients. They are available as manganese, zinc and copper sulphates, oxides, oxy-sulphates and chelates, as well as in boric acid and ammonium molybdate.

Entire focus on use of fertilizers have been almost exclusively on NPK since their "discovery" in the mid-1800s. Owing to the role of these primary nutrients in the crop cycle, they have been overused to increase the production without realizing the long-term effects on the soil and environment. Thus, the negative impact of fertilizers has often been highlighted. But as the fertilizers are required for proper growth of plants, and plants are the primary source of food for human and animal consumption, the former does have an impact on human and animal health as well.

#### **Impact of micronutrients on human health**

As seen in the case of micronutrients, mineral elements like Zn, Fe and Cu are as important as compounds like carbohydrates, fats, protein and vitamins for human development. Micronutrient deficiencies in soils limit crop yields and nutritional quality, which in turn negatively affect human health (Marschner, 2012; Alloway, 2009). Micronutrient intake less than the recommended values can cause slower physiological processes. High consumption of cereal-based foods with low contents of micronutrients is causing health hazards in humans (Imtiaz *et al.*, 2010).

Micronutrient malnutrition, the so-called hidden hunger, affects more than one-half of the world's population, especially women and preschool children in developing countries (Welch and Graham, 2004). Worldwide over 2 billion people suffer from iron (Fe), zinc (Zn) and/or other (multiple) micronutrient deficiencies (WHO, 2016; Black, 2003). The problem is most severe in low and middle-income countries (Muthayya *et al.*, 2013). The physiological impacts of micronutrients are complex, relating to many bodily functions. Even mild to moderate deficiencies of micronutrients can lead to severe health problems.

**Selenium:** Selenium has important antioxidant, anti-cancer and antiviral properties and its deficiency makes human prone to thyroid dysfunction, cancer, severe viral disease and various inflammatory conditions (Lyons *et al.*, 2004).

**Zinc and Iron:** Iron deficiency is the prominent cause of anaemia which contributes to compromised physical productivity, cognitive impairment and adverse pregnancy outcomes. Likewise, Zn deficiency has been related to growth failure, decreased immunity leading to increased susceptibility to infection, morbidity and mortality due to diarrheal disease, and the incidence of respiratory tract pneumonia (Etcheverry *et al.*, 2005), impaired growth and development of infants, children and adolescents, as well as impaired maternal health and pregnancy outcome (Martin, 2004). Trials conducted in several countries indicate that duration and severity of major baby-killers such as diarrhoea and pneumonia can be reduced by 30-50 % by supplying adequate amounts of vitamin A and zinc (Bhargava *et al.*, 2001). In developing countries, zinc deficiency ranks 5th among the leading 10 risk factors. Even on a global scale, taking developed and developing countries together, zinc deficiency ranks 11th out of the 20 leading risk factors. WHO attributes 800,000 deaths worldwide each year to zinc deficiency and over 28 million healthy life years



lost. It is estimated that zinc deficiency affects one-third of the world's population, with estimates ranging from 4 to 73% according to regions, and it is 5th leading risk factor along with the Fe deficiency, the latter is at 6th position globally.

### **Advanced technology to mitigate harmful effect of micronutrients and on its content in foodstocks**

#### **Chelation as an efficient delivery system**

Chelation is the most advanced delivery system for crop nutrition which converts metal nutrients into inert, water soluble compounds, thus making the crop nutrients incapable of any harmful chemical reactions once applied to the soil and crops. This protects the fields from harm caused by inorganic fertilizers.

The challenge of integrated nutrient management may be addressed by creating a range of specialty plant nutrient products that are chemically inert in nature. This process is known as Chelation Technology and has been successfully adapted to the agricultural sector. The process involves taking positively charged metal nutrients like zinc, iron, copper, manganese, magnesium, etc. and enveloping these ions with a negatively charged chelating agent. Once this process is complete, the end-product is a stable complex, which is chemically inert until it enters the plant system. The enzymes inside the plant system reactivate the product and release the nutrients to the crop. Thus, chelation is a delivery system which leads to the nutrients being delivered to the plant in its most unharmed form. Post-delivery of the nutrients, the chelation agent is released back into the root zone and it attracts heavy metals (positively charged metals) like lead, arsenic, cadmium, etc. and neutralizes these toxins in the soil thereby rendering them inactive and incapable of causing further harm to the crop. This residual effect is an added advantage of chelation technology.

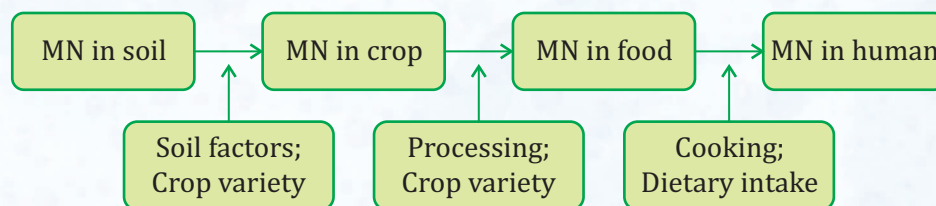
Specific formulations containing various nutrients required by different crops based on soil, crop and geographic conditions have also been created. This makes it very simple for the farmer to access specific formulations as per crop requirement. Chelation in India largely uses synthetic chelating agents like EDTA, DTPA, EDDHA, etc. However, soya protein also provides a safe, cost-effective natural alternative to providing chelated nutrients to crops.

#### **Economic benefits of chelation technology**

Chelates remain inert till they are absorbed into the plant system. There is zero wastage and a reduction in dosage upto 20 times compared with the traditional inorganic nutrient application. Thus, a farmer applies only 500 g of a chelate versus 20 kg of a sulphate of the similar nutrient. Despite the low dose of the chelate, yields are reported to increase by an average of 30%. Cost-benefit consequently is very favourable, with a farmer gaining on average Rs 6/- for every Re1/- invested in chelated nutrients, experimentally observed.

#### **Improving micronutrient content in foodstocks**

Micronutrient content of food can be increased either by supplementation, fortification or by agricultural management strategies. The process of food fortification and supplementation are too expensive and hence impractical to be applied on large scale, hence not easily accessible to poor masses. A suggested strategy to alleviate micronutrient deficiencies is agronomic biofortification, particularly of staple foods, and application of micronutrients containing fertilizers. Genetic biofortification involves either genetic engineering or classical breeding. Agronomic biofortification is achieved through micronutrient fertilizer application to the soil or application directly to the leaves of the crop (foliar application). The impact of agronomic biofortification largely depends on the bioavailability of micronutrients throughout the pathway from soil to plant, from plant to food, and uptake by the human body (Fig. 1).



**Fig. 1. Schematic overview of micronutrient pathway from soil to humans and the factors that influence its bioavailability (Mayer *et al.*, 2011)**



Interactions between micronutrients and macronutrients can influence the effectiveness of agronomic biofortification. Adequate N and P status of plants has a positive influence on root development, shoot transport, and re-localization of nutrients from vegetative tissue to the seeds (Prasad *et al.*, 2014; Cakmak *et al.*, 2010). This results in increased micronutrient uptake and concentrations in the edible parts of the crop. There are several critical factors that play a key role to determine the success of agronomic fortification to overcome micronutrient deficiencies among humans. These factors depend on nutrient bioavailability at different stages: the presence and bioavailability of soil nutrients for plant uptake, nutrient allocation within the plant, re-translocation into the harvested food, and availability of nutrients in prepared food for uptake in the human body. Bioavailability from soil to crop is influenced by many soil factors (*viz.* pH, organic matter content, soil aeration and moisture and interaction with other elements) and the crop variety that, for example, defines the functioning of rooting systems. Bioavailability from crop to food is influenced by the crop variety (which defines the allocation and re-localization of micronutrients into edible parts of the crop) and processing of the harvestable part (*i.e.*, milling and dehusking). Bioavailability from the food for the human body is influenced by cooking of food and dietary intake such as, the amount of food consumed, diet composition and individual health status (de Valença and Bake, 2016).

### **Impact of micronutrient on animal health**

In animals, micronutrients are required in diet for their overall improved health and also essential for production of egg, meat and milk. The importance of micronutrients can be very well realized by the fact that their deficiencies in animal diet can lead to restricted growth and reduction in animal productivity. Fe, Zn, Cu, Mn, Mo, Se, I and Co are the essential elements which play pivotal role in animal health and each element play at least a major role in physiological functioning of animal (Table 1).

**Table 1. Deficiency symptoms and the major role by micronutrients in ruminant livestock (Fischer, 2008)**

Element	Role	Deficiency symptom / Diseases
Fe	Protein and enzyme function. Blood haemoglobin.	Anemia
Cu	Haemoglobin formation, enzyme function, and pigments	Anaemia, poor growth, bone disorders, infertility, brain and spinal cord lesions. Decolouration of hair.
Co	Vitamin B12 function and energy assimilation.	Poor growth, anaemia, loss of coat, low immunity to disease, infertility
Se	Vitamin E function	Poor growth, white muscle disease, infertility
I	Thyroid gland function	Goitre and reproductive failure
Mn	Enzyme activation	Enzyme activation
Zn	Enzyme function	Stiff and swollen joints, parakeratosis.
B	Enzyme function	Weak bones, poor immune function

It is imperative to have a balanced and holistic approach to overcome micronutrient deficiencies in practical farm situations as mentioned by Fischer (2008).

- Treating the soil with fertilizers and nutrients particularly in which the soil and animal is likely to be deficient.
- Treating the fodder or herbage with micronutrients through foliar spray.
- Treating the animals by using feeding blocks and licks
- Supplementation of micronutrients through feed.
- Directly injecting the animals with nutrients



### **Effects and Inferences**

When micronutrient demand and supply are in sync, there should be no serious negative environmental effects seen within the agricultural ecosystem. Micronutrients generally bind strongly to the soil and thus are not susceptible to loss into the environment which minimizes risks of environmental pollution. Furthermore, micronutrients improve crop health, which reduces the need for agrochemicals (pesticides, herbicides, fungicides, etc.). Accumulation in soils due to overuse may cause toxicity problems. The globally available mineral reserves of micronutrients are limited, which highlights the importance of nutrient recycling for long-term sustainable micronutrient availability for agricultural production.

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**ARTICLE - 5**

**Assessing the mitigation potential of greenhouse gas emissions in terms of C balance in climatically vulnerable villages using EX-ACT Tool\***

Climate change is taking a toll on crop production given the fact that crop cultivation is a weather dependent enterprise. Increasing temperature, heat and cold waves is affecting crop performance adversely. Flagrant temporal and spatial variation in rainfall is causing flood and drought spells and is altering water availability of crops. Also rapid oxidation of SOC on account of increase in surface temperature is a major concern for soil fertility.

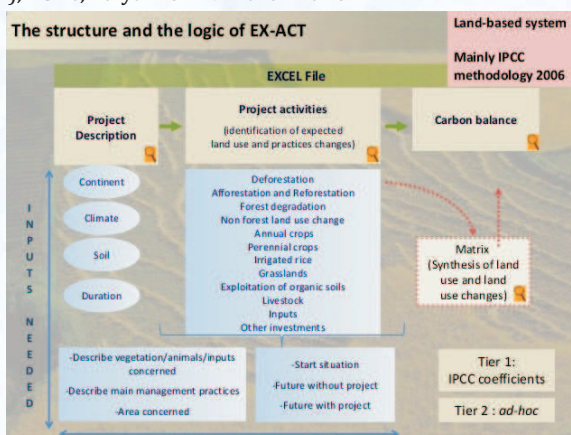
Now, we have reached a point where complete mitigation of climate change is not attainable. Hence, we have to adapt ourselves to our changing environment. As such, Climate Resilient Agriculture is the need of the hour. Climate resilient agriculture is built on three pillars - increasing productivity and incomes, enhancing resilience of livelihoods and ecosystems, and reducing GHG emissions from the atmosphere. Towards this end, Indian Council of Agricultural Research (ICAR) launched the National Innovations in Climate Resilient Agriculture (NICRA) project in 121 vulnerable districts of the country during 2010-11.

**Model for measuring impact of climate change and methodology used**

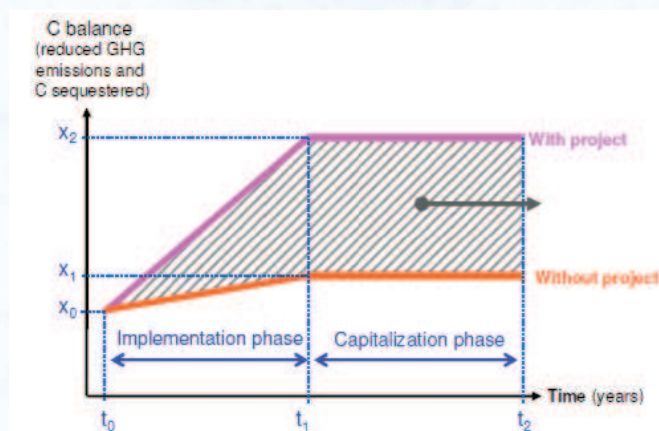
For measuring the impact of climate change on crop growth, a suitable model namely, Ex-ACT has been used in a few climatically vulnerable villages spread across Gujarat, Rajasthan, Andhra Pradesh, Telengana and Maharashtra states of India. It allows the user to input their own emission factors to take a Tier-II approach and provides Ex-ante measurements of GHG emissions and C sequestration, indicating its effects on the C balance. The emissions are expressed in  $tCO_2e\ ha^{-1}$ . The three divisions of FAO namely, TCA (Policy Assistance and Resources Mobilization Division), ESA (Agricultural Development Economics Division) and TCI (Investment Centre Division) have developed EX-ACT model. This model is a set of linked Microsoft Excel sheets with six modules based on land use and management practices using IPCC default values (Tier-I) and/or region-specific coefficients (Tier-II) comparing the situation without and with project. The structure and logic of Ex-ACT are shown in Fig.1. Fig. 2 presents schematic representation of the model,

The default values in the model for mitigation options in the agriculture sector were taken mostly from IPCC (2007) and other coefficients like embodied GHG emissions for farm operations; while inputs on transportation and irrigation systems implementation were taken from Lal (2004). The main output of this tool consists of the C-balance resulting from the difference between the two alternative scenarios i.e., with project (climate resilient practices) and without project (farmers' practices) scenarios for a period of 20 years, with implementation phase of 5 years and capitalization phase of 15 years. Below is a schematic representation of the model for computing C-balance.

\*Extracted from the Invited lecture of Dr. K. Sammi Reddy, Director (Actg) CRIDA Hyderabad with permission during 5th Annual Convention and National Seminar-cum-AGM of the Society for Fertilizers and Environment on "Agri-chemicals for a benign environment", held at FACC (Lake Hall), BCKV, Kalyani on 29 March 2018



**Fig. 1. The structure and logic of EX-ACT**



**Fig. 2. Schematic representation for computing final C-balance using Ex-ACT  
*Climate resilient interventions***

A number of climate resilient practices had been demonstrated under NICRA with an objective to enhance the adaptive capacity to the growing climate risks. Some of these practices are being accepted by the farming community and are being scaled up not only in the village but also across the villages. A number of these practices besides enhancing the adaptive capacity also contributes to the mitigation. Table 1 enumerates different climate resilient interventions which have been adopted in the identified climate resilient villages under NICRA.

**Table 1. Details of the interventions adopted in the study villages under NICRA project**

Practices	Improved practices	Traditional practices
Crop management	Adopting improved cultivars	Adopting Local varieties
	Zero tillage	Intensive cultivation with 2-3 ploughings and disc harrowing
	Crop diversification with legumes	No crop diversification
Water saving technologies	Micro-irrigation	Normal tubewell and canal irrigation
	Insitu moisture conservation	No conservation measures for moisture
	Water harvesting	No such water harvesting
	Rice cultivation (intermittent flooding)	Rice cultivation with flooding
Nutrient management interventions	Soil test based nutrient use (Rationale use)	Blanket application
	Improving Nitrogen use efficiency (avoiding residue burning and incorporating crop residues, soil test-based fertilizer application, split application)	No such practices
	Green manuring	Not practiced
	Composting	Not practiced
	Leaf colour charts	Not practiced
Livestock interventions	Biogas slurry	Not practiced
	Improved feeding practices (green fodder, mineral mixtures, rice bran etc)	Grazing and rice straw feeding
	Improved breeding practices (artificial insemination, avoiding in breeding etc)	Inbreeding



Village level C balance studies have been conducted in the climate vulnerable villages of 6 districts of Andhra Pradesh. Change in C Balance have been calculated for annual and perennial crops, fertilizer use and livestock, and are given in Tables 2-4.

**Table 2. Change in C balance (t CO<sub>2</sub>-eq) due to adoption of climate resilient management practices in different annual and perennial crops in the study villages**

Village	Annuals		Perennials	
	C balance (t CO <sub>2</sub> -eq) in total modeled area for 20 years	Per ha per yr C balance (t CO <sub>2</sub> -eq ha <sup>-1</sup> yr <sup>-1</sup> )*	C balance (t CO <sub>2</sub> -eq) in total modeled area for 20 years	Per ha per yr C balance (t CO <sub>2</sub> -eq ha <sup>-1</sup> yr <sup>-1</sup> )*
Khunttil	-2151	-0.54	-8367	-4.50
Magharvada	-10393	-0.42	--	--
Bhalot	-8646	-0.36	-531	-3.54
Bharu	-9001	-0.81	--	--
Sitara	-2492	-0.27	--	--
Purkhawas	-3504	-0.19	-1770	-5.90
Chomakot	-8101	-0.79	--	--
Mean	-6327	-0.48	-3556	-4.65
SD	3214		3439.29	
CV	-0.51		-0.97	

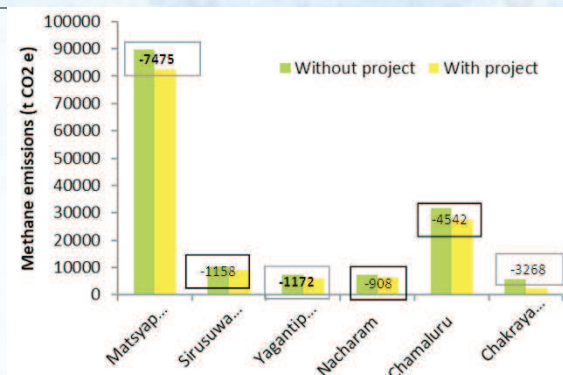
Change in methane emission from irrigated rice cultivation was also computed and represented in Fig.3.

**Table 3. C emission and balance (t CO<sub>2</sub> e) due to fertilizer use**

Village	Total Emission		Balance
	Without Project	With Project	
Nacharam	55969	58533	2564
Nandyalagudem	18557	16068	-2489
Boringathanda	10685	9144	-1541
Yagantipalli	39972	30104	-9868
Matsyapuri	37110	31849	-5261
Sirusuwada	7844	6926	-918
Chamaluru	40456	25774	-14682
Chakrayapet	3242	2065	-1176
- Carbon Sink and + Carbon source			

**Table 4. C balance under improved livestock management**

Village	CH <sub>4</sub> from enteric fermentation	CH <sub>4</sub> from manure management	N <sub>2</sub> O from manure management	Improved feeding practices	Final balance
Chamaluru	9044	407	4131	-608	12975
Chakrayapet	343	27	100	-75	395
Nacharam	1222	111	184	-55	1461
Yagantipalli	3694	343	469	-462	4045
Sirusuwada	1979	171	457	-292	2315
Matsyapuri	0	0	0	-340	-340
Nandyalagudem	318	23	116	-74	383
Boringthanda	814	75	199	-134	954



**Fig. 3. Change in methane emission due to improved rice cultivation**

***Options for appropriate interventions suggested for mitigation of greenhouse gas emissions***

The results obtained from the output of the model revealed that the increase in sink capacity across the villages ranged from 16.4 (Chomakot) to 96.9% (Khuntil) in annual crops; 4.8 (Bhalot) to 63.8% (Khuntil) in perennials; 3.1 (Chomakot) to 39 % (Magharvada) due to fertilizer management except in Khuntil where the emissions were 64.9%. The source capacity (emissions) ranged from 17 (Magharvada) to 93.2 % (Bharu) in livestock and 6.8 (Bharu) to 83% (Magharvada) due to non-forest landuse change except in Khuntil where a sink of 15.2% was observed. In case of irrigated rice, cultivated in two villages, a sink of 4.6% (Khuntil) and emission of 12.8% (Chomakot) were observed. Interestingly, when all the sources and sinks were considered from different systems individually due to adoption of climate resilient practices in each village, there was a sink where its capacity varied from -1621 to -10410 t CO<sub>2</sub> equivalent. The interventions adopted (improved cropland management, nutrient management, water management) were proven to be appropriate options to mitigate the carbon dioxide (CO<sub>2</sub>) emissions for the next 20 years with mitigation potential up to 86.6 % of the total GHG mitigated.

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**Upcoming events of the Society:**

One National Seminar on “Agri-chemicals for a benign environment” in collaboration with Bidhan Chandra Krishi Viswavidyalaya on the occasion of the 5<sup>th</sup> Annual Convention of our Society to be held on March 29, 2018 at the FACC (Lake Hall), BCKV, Kalyani.

**Editors: H. S. Sen, Biswapati Mandal, Dipankar Ghorai,  
F. H. Rahman and Dibyandu Sarkar**

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