



# Fertilizers and Environment News

Society for Fertilizers and Environment

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## From President's Desk



### Managing agrochemicals for crop and environmental health: use of alternative protocols

Globally there is need to increase crop production by 60% to meet hunger, and soils, 33 % of which are degraded, play stupendous role. In the previous issues I discussed on this column broadly the potentials and uses of agrochemicals including fertilizers and pesticides on the adverse impacts on soil and the environment. Massive use of inorganic fertilizers worldwide is associated with the accumulation of contaminants, e.g. those which can directly affect an integral part of the plants and modify their biochemical, metabolic and physiological processes. Some of the heavy metals such as Cu, Mn, Co, Zn and Cr are important for the completion of metabolic activities, although in trace quantities. The soil health being the key factor is interlinked with the soil biochemical health and soil enzyme activities, and they can be the most important quality indicators in agrochemical-contaminated soils. Environmental pollution due to toxic gas emission was noticed as the primary factor for global climate change due to improper use of agrochemicals. Recent approaches for a precise and better application of pesticides would be useful in reducing ecotoxic effects and preventing human health hazards. Further developments to popularize alternative protocols, such as biopesticides, organic pesticides, novel biocontrol agents, and nanopesticides, should be emphasized to avoid the careless application of agrochemicals (Mandal et al., 2020; DOI:10.1016/B978-0-08-103017-2.00007-6).

Organic pesticides are usually considered as those pesticides that come from natural sources. These natural sources are usually plants, as is the case with pyrethrum (pyrethins), rotenone or ryania (botanical insecticides), or minerals, such as boric acid, cryolite, or diatomaceous earth. Organic pesticides are largely the insecticides.

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Biopesticides can be classified into the following classes:

- Microbial pesticides consist of bacteria, entomopathogenic fungi or viruses (and sometimes includes the metabolites that bacteria or fungi produce). Entomopathogenic nematodes are also often classed as microbial pesticides, even though they are multi-cellular.
- Bio-derived chemicals - Four groups are in commercial use: pyrethrum, rotenone, neem oil, and various essential oils are naturally occurring substances that control (or monitor in the case of pheromones) pests and microbial diseases.
- Plant-incorporated protectants (PIPs) have genetic material from other species incorporated into their genetic material (*i.e.* GM crops). Their use is controversial, especially in many European countries.
- RNAi pesticides, some of which are topical and some of which are absorbed by the crop.

A major growth area for biopesticides is in the area of seed treatments and soil amendments. Many biofungicidal products also show capacities to stimulate plant host defence and other physiological processes that can make treated crops more resistant to a variety of biotic and abiotic stresses. The market for agricultural biologicals worldwide will reach \$19.5 billion by 2031 as predicted by market research companies. The limitations to widespread use in India are short shelf life, production and application protocols, narrow range of target pests and pathogens, difficulty in delivery system, economics and regulations, apart from lack of push from the government – all leading to not too encouraging performance in the field.

Due to its high potential as alternative/complement to conventional pesticides, biological disease control is now generally recognized to constitute an important tool in integrated pest management (IPM). Novel biocontrol agents are the use of microorganisms or biological methods to control plant diseases and pests, and called as biocontrol. The

agents which are used to control the microbes are called biocontrol agents. These may be bacteria: black flies, caterpillars, larvae, wax moths; say *Bacillus thuringiensis*.

Role of nanoparticles in agriculture, in the fields of both fertilizer and pesticide applications, apart from plant genetic transformation, is revolutionary. In general, a nanoparticle is defined as any particle where one characteristic dimension is 100nm or less. This is primarily the consequence of a high proportion of atoms being present on the surface, with an increased proportion of sites operating at higher reactivities with respect to processes such as adsorption processes and electrochemical interactions.

In the field of fertilizer applications, it has tremendous uses and lot of research has already gone into and still being conducted worldwide. Nanopesticides are plant protection products where nanotechnology is employed to enhance the efficacy or reduce the environmental footprint of a pesticide active ingredient (CSIRO). At the moment there are at least three different formulation types—nanoemulsions, nanocapsules and inorganic engineered nanoparticles (ENPs) — at different stages in the product development cycle. All of them can be used to improve the efficacy of the active ingredient in the pesticide itself or improve the safety of the products in the environment. Currently, there is little understanding of the risk associated with this emerging technology, according to the CSIRO. The framework of a study further by IUPAC focusses on human health risk assessments for nanopesticides, as well as nanofertilisers through a decision tree and pathways to risk assessment (<https://iupac.org/guiding-principles-for-the-regulatory-evaluation-of-nanopesticides/>).

**H. S. Sen**  
*President*



## NEWS

### 8<sup>th</sup> Annual Convention including the AGM and Webinar

The 8th Annual Convention of the Society for Fertilizers and Environment and the Annual General Meeting was organised on March 30 and 31, 2021 along with a National Webinar on “**Stewardship to Agrochemicals for Upkeeping Environment**”. In view of the imposed restrictions due to COVID, the event was organised online through Google Meet. The National Webinar comprised of presentation of relevant research findings by budding scientists related to fertilizers and environment in a poster session on 30.03.21 and National Webinar on 31.03.21. The posters were segregated into two separate themes as hereunder,

#### Theme I: Fertilizer in Crop Production and Soil Health Management

#### Theme II: Environmental issues related to Agro-chemicals

Three best posters were selected by the juries from each theme and were awarded with certificates and the recipients are as hereunder,

#### Theme I: Fertilizer in Crop Production and Soil Health Management

1st	Susmit Saha, Sovan Debnath, Dibyendu Sarkar, Kaushik Batabyal, Sidhu Murmu, Biswapati Mandal	Assessing Zn induced Fe depletion in Foods made up of Zn fortified cereal grains
2nd	Deblina Ghosh, Sidhu Murmu	Sulphur extractability in soil and its relation with crop under a long term fertility experiment

#### Theme II: Environmental issues related to Agro-chemicals

1st	Bishnuprasad Dash, Vipin Kumar and R.K. Jat	Conservation agriculture influences organic carbon pools and quality of soils
2nd	Debjyoti Majumder, Rakesh Roy, Suddhasuchi Das and B.C. Rudra	How well do the Rice Simulation Model (ORYZA2000) able to reproduce realistic rice yield over old alluvial Zones of West Bengal
3rd	Siddhartha Mukherjee, Biswabara Sahu, Puja Singh, Joy Dutta, Dibyendu Sarkar, Uday Pratap Singh	Efficacy of conservation agriculture for stabilizing carbon and nitrogen in soils of Eastern Indo-Gangetic Plain

The National Webinar was organized on 31.03.21. Prof. Panjab Singh Chancellor, RLBCAU Jhansi and Former Secretary DARE & DG, ICAR was the CHIEF GUEST during the occasion. Prof. Biswapati Mandal, Secretary, SFE welcomed all the participants on behalf of the Society and in his remarks enlightened the participants about the Society’s aims and goals in the wake of increasing fertilizer related soil disorders which was followed by the release of Society’s Newsletter, Volume 7, Issue 1.

Prof. Panjab Singh, Chief Guest during the occasion then in his inaugural address called upon the participants to reform, perform and transform agriculture for sustainable production to feed 1.7 billion people of India by 2051-52. He expressed his concern towards steady depletion of natural resources with concomitant adverse effect on environment and lauded the society’s activities towards creating mass awareness among all stakeholders of agriculture. He also pointed out to policy issues like strengthening of rural infrastructures and more funding in research activities for transformation of Indian agriculture.

Dr. H. S. Sen, President, SFE then in his opening remarks pointed to the noxious effect of agrochemicals for human health, ecosystem and environment and urged for alternative strategies to agrochemical use for environmental sustainability. He emphasized on use of biofertilizers, IPM measures and biopesticides for augmented crop and human health vis-à-vis environment protection. He was of the view that specific mechanisms and genes involved for bioremediation and detoxification of pollutants may be explored and that there is need to investigate site-specific microbial communities under a wide range of environmental conditions.

The 5<sup>th</sup> Foundation Lecture of the Society was delivered by Dr. A. N. Ganesmurthy, ICAR Emeritus Scientist. He spoke on “**Legacy Nutrients In Horticulture Fields - Need for Good Agriculture Practices**”. He opined that excess fertilizer use has caused soil nutrients to accumulate in the traditional breadbaskets. He expressed his concerns on overuse of phosphatic



fertilizers causing litany of environmental ill like eutrophication. According to him intensity of fertiliser use in India remains much lower than most countries in the world but is highly skewed, with wide inter-regional, inter-state, and inter-district variations and as such urged upon the participants to inculcate fertilizer best management practices (FBMPs) among farming community which are agricultural production techniques and practices developed through field researches and verified in farmers' fields to maximize economic, social and environmental benefits.

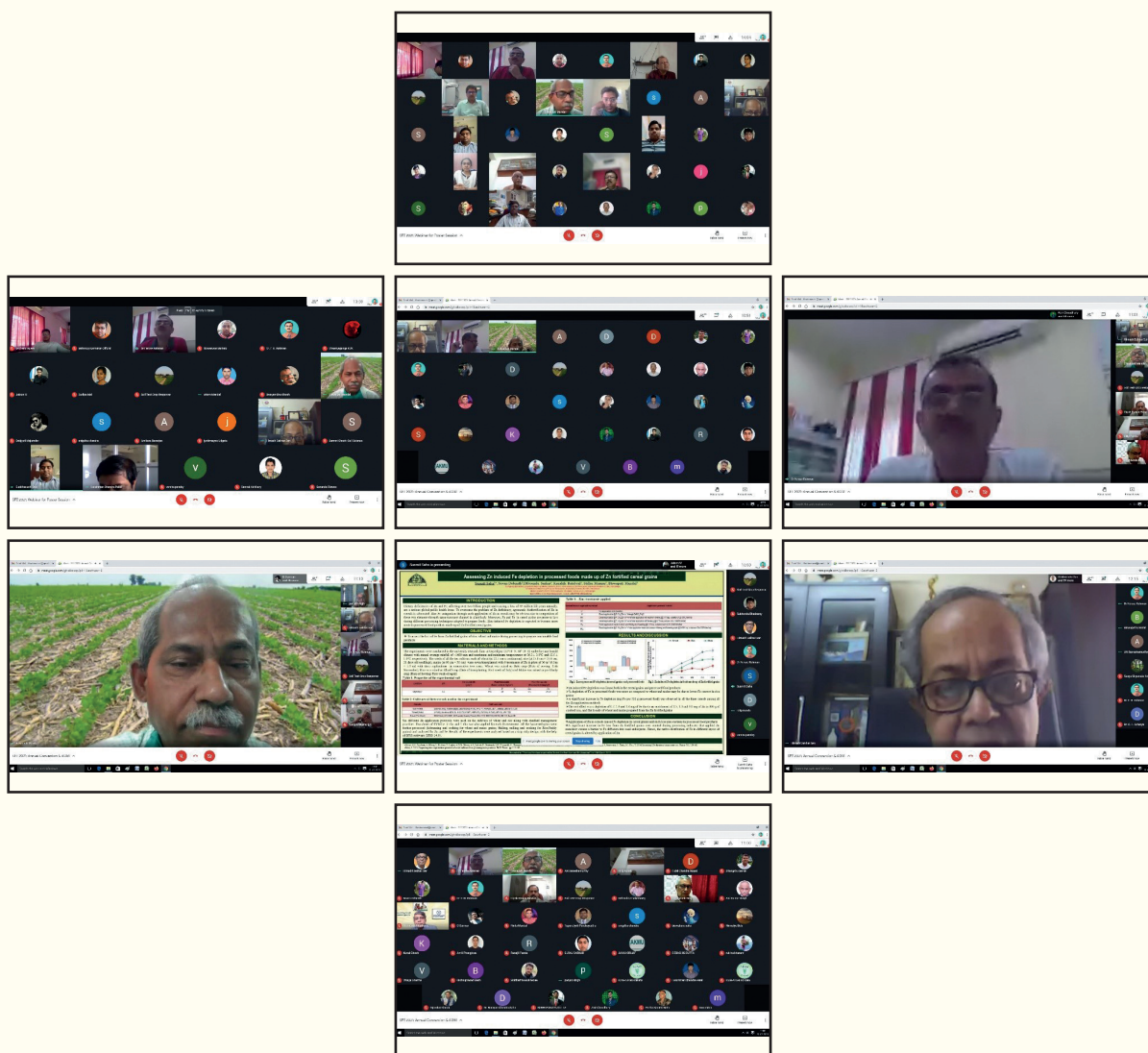
The 3rd Dr. N. P. Datta memorial lecture was delivered by Dr. S. Bhadraray of Rallis India Ltd. He emphasized on increasing fertilizer use efficiency and as such industry's prerogative to make tailor made customized fertilizers and nanofertilizers for transforming country's agriculture. He stressed on more use of water soluble fertilizers for better crop nutrition. He shared with the participants about Tata Rallis' initiative on making customized fertilizers and presented success cases in making use of the same.

Afterwards, the best poster awardees presented their research findings in details which were thoroughly appreciated the budding scientists for their endeavour.

The Convention ended with vote of thanks by Dr. F. H. Rahman, Jt. Secretary of SFE.

It was followed by Annual General Meeting of the society presided over by the president of the society where Dr. D. Sarkar, Treasurer of the Society presented the annual accounts statement and the future plan of action was chalked out in the meeting.

***Glimpses from the National Webinar:***





## ARTICLE 1

### Arsenic accumulation in different rice cultivar (*O. sativa* L.) groups and human health risks: a study in an arsenic hotspot

#### Introduction:

An estimated 200 million people worldwide have been reported to be at risk of arsenic (As) poisoning, either directly by drinking As-contaminated groundwater or indirectly via ingestion of As-laced food crops, mainly rice (*Oryza sativa* L.) irrigated with As-contaminated groundwater (Samal *et al.*, 2021). Accumulation of As from soils to human diets poses a serious health risk to humans, as it is considered as class I carcinogenic element, and a causal agent for a large number of human ailments e.g., weakness, chronic respiratory disease, liver fibrosis, cardiovascular diseases, skin cancer and lung cancer

Rice is the foundation of food security for population of South Asian countries. It has a higher tendency for As uptake than other cereals as it is grown under submerged soil conditions inducing reductive dissolution of iron oxyhydroxide minerals and reduction of As adsorbed on soil minerals, increasing dissolved concentrations, and thus its plant availability. A number of studies showed substantial genetic variation amongst the rice genotypes in sequestering As into grains. The aim of this study, therefore, is to elucidate the translocation pathways of As from soil to cooked rice and assess its health risk on consumption using fifteen widely cultivated rice cultivars covering all the three distinct groups viz., HYVs, LARs and hybrids.

#### Materials and methods:

##### *Experiment site*

The experiment was conducted in a farmer's field at Chakdah (N 23°01.899' and E 88°34.715'), West Bengal. The experimental soil was *Aeric Endoaquept* with silty clay loam texture, neutral in reaction (pH 7.0) and low in organic C (5.3 g kg<sup>-1</sup>). The Olsen extractable and total soil As were 2.64 and 12.06 mg kg<sup>-1</sup>. The level of As in the groundwater used for meeting irrigation requirements of rice grown varied from 0.083 to 0.128 mg L<sup>-1</sup>. We used fifteen rice cultivars belonging to three distinct groups viz., high yielding variety (HYV), local aromatic rice (LAR) and hybrid rice.

##### Sample collection and preparations

Shoot, root and grain (on maturity) of all the 15 cultivars were collected replication-wise at three different growth stages, viz., tillering, booting and maturity. On drying at 65 °C in an oven for 48 hours, the samples were ground with the help of a stainless-steel mini-grinder. The dried rice grain from each of the cultivars with four replications was subjected to de-hulling to produce brown rice and husk. Polished rice thus prepared from all the 15 cultivars with 4 replications were cooked following two methods (cooking with excess water and pressure cooker method) traditionally used in this part of the Southeast Asian countries.

#### Result and Discussion:

##### *Arsenic profile in rice cultivars at different growth stages*

Arsenic concentration in roots and shoots of rice cultivars varied significantly over the growth stages. On average, its concentration in roots at tillering was 3.07, 1.16 and 3.9 mg kg<sup>-1</sup> which increased by 2.7, 2.1 and 2.5 folds at booting and 2.94, 2.97 and 2.70 folds at maturity in HYVs, LARs and hybrids, respectively. Arsenic concentration was lower at tillering and increased with crop growth. At maturity, the trend of shoot As was: hybrids (4.48 mg kg<sup>-1</sup>) > HYVs (3.81 mg kg<sup>-1</sup>) > LAR (1.17 mg kg<sup>-1</sup>). On average, transfer factor (TF) of As from root to shoot (TFr-s) and shoot to grains (TFs-g) had the following trend: hybrids (0.41 and 0.31) ≥ HYVs (0.42 and 0.30) > LARs (0.37 and 0.17); Of the three groups of cultivars, LARs had the highest content of the DCB-extractable iron (Fe-plaque) at all the three growth stages viz., tillering, booting and maturity with magnitude of 1852, 2940 and 2421 mg kg<sup>-1</sup> for LARs, 1767, 2522 and 2360 mg kg<sup>-1</sup> for HYVs and 1526, 2250 and 2057 mg kg<sup>-1</sup> for hybrids, respectively. The Fe-plaque also showed significant negative correlation with bioaccumulation factor (BAF) at all the growth stages. However, the relationship was stronger at booting stage ( $r = -0.717$  \*\*).

**Arsenic distribution in parts of rice grain**

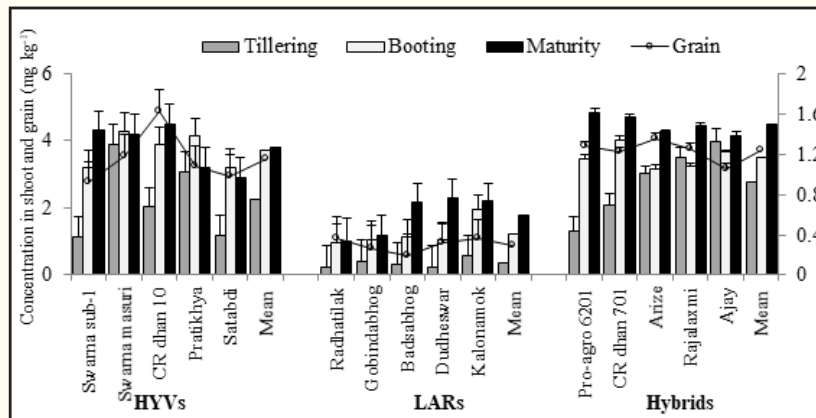
It was observed that the husk sequestered ~45, 51 and 47%, while the bran 34, 33 and 29%, cumulatively 82.4, 85.4 and 77.2% of the total grain As of HYVs, LARs and hybrids, respectively. It thus indicated that the hybrids (23%) retained a higher proportion of their grain As in the edible part in endosperm (polished rice) compared with that of the HYVs (18%) and LARs (15%). Irrespective of cultivars, As distribution in grain fractions thus skewed in husk and bran and followed the trend: husk > bran > polished rice. To date, the As sequestration mechanism in the husk and bran is unclear.

**Arsenic in cooked rice**

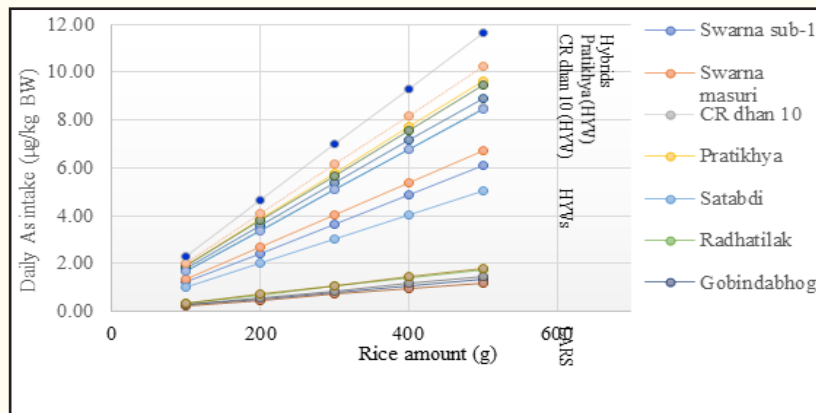
There are different methods available for cooking rice across the world. We cooked rice with two methods – with excess (water: rice :: 6:1) and limited (water: rice :: 2.5:1) water and used water of two qualities, contaminated and non-contaminated with As. Cooked rice prepared out of these combinations had the following trend of As concentrations: cooked with contaminated limited water > raw rice > cooked with non-contaminated limited water > cooked with contaminated excess water > cooked with non-contaminated excess water.

**Risk assessments**

We evaluated the threats posed by computing a number of indicators viz., ADI, HQ and ILCR used, of late, for the purpose. The estimated daily intake of As through consumption of cooked rice originated from the tested cultivars varied among themselves 10-folds from 0.24 to 2.3 µg kg<sup>-1</sup> BW. Such intake was much lower with LARs (0.24-0.36 µg kg<sup>-1</sup> BW) compared with HYVs (1.01-1.93 µg kg<sup>-1</sup> BW) and hybrids (1.79-2.33 µg kg<sup>-1</sup> BW) (Fig 2). Again, we assessed both the carcinogenic (ILCR) and non-carcinogenic (HQ) risks through consumption of the cooked rice prepared from the polished rice of the testing cultivars. In fact, LAR had 5- and 6.8-folds lower values of HQ than that of HYVs and hybrids, respectively. It indicates, LARs possessed the low threat for non-carcinogenic hazard posed over HYVs and hybrid groups



**Fig.1 Concentration of As in shoots of the tested rice cultivars viz., high yielding varieties (HYVs), local aromatic rice (LARs) and hybrids at tillering, booting and maturity stages and in grains**



**Fig. 2. Estimated daily intake of total As from consumption of cooked rice prepared from the tested cultivars belonging to high yielding varieties (HYVs), local aromatic rice (LARs) and hybrids**



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## ARTICLE 2

### **Efficacy of conservation agriculture for stabilizing carbon and nitrogen in soils of Eastern Indo-Gangetic Plain**

**Introduction:**

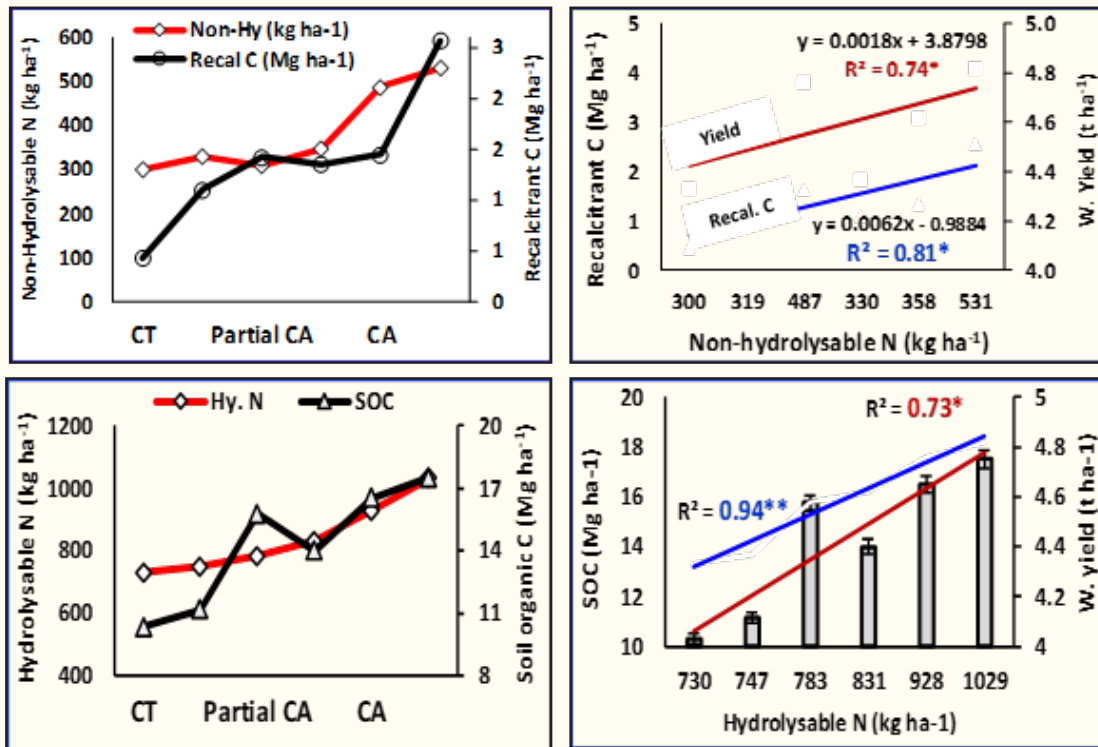
Intensified tillage-based farming systems have caused serious deterioration in natural resources with high environmental footprints. To curb these, conservation agriculture (CA) with minimum soil disturbance, increased residue retention, and diversified crop rotation is being popularised (Jat *et al.*, 2019; Alam *et al.*, 2019, 2020; Page *et al.*, 2020). The behaviour of carbon (C) and nitrogen (N) in soils under CA is different from conventional agricultural practices due to the change in tillage intensity, residue management, and crop diversification (Mazzoncini *et al.*, 2011; Chao *et al.*, 2019). CA increases the mass of C stored in agricultural soils so as to check its increasing concentration in the atmosphere (Govaerts *et al.*, 2006; Gál *et al.*, 2007). Lack of soil aeration because of lack of tillage in CA causes specific changes in soil physical and biological conditions that not only facilitates the increase of soil C stocks but also influences soil N dynamics as C and N in soil organic matter are biologically linked together and complement each other (Kelley and Stevenson, 1996; Pasricha *et al.*, 2017). Therefore, an alteration in the forms of C and N and their dynamics in soils under CA is expected over conventional agricultural practices.

**Materials and Methods:**

A field experiment was conducted at Banaras Hindu University (BHU) farm with different intensities of tillage (conventional tillage, CT; zero-tillage, ZT) and crop residue retention (R) under rice-wheat (RW) and rice-wheat-mung bean (RWM) cropping systems to determine the impact of CA on soil C and N stabilization. Soils were collected from 0-20 cm depth after fifth *rabi* crop (wheat) and analysed for different forms of C and N. The oxidisable soil organic carbon (SOC) was analysed by chromic acid titration method (Walkley and Black, 1934) and the recalcitrant carbon pool was calculated by subtracting SOC from total organic carbon (TOC) (Chan *et al.*, 2001). All the identifiable forms of the organic forms of N were also analyzed following the standard protocol (Bremner, 1965; Stevenson, 1996) to unearth the mechanism of CA in imparting N stabilization in soil.

**Results and Discussion:**

Results showed that C stabilization recorded an increase with the intensity of CA and was more pronounced with RWM cropping system. On average, CA practices *viz.* ZT(RW)+R(RW) and ZT(RWM)+R(RWM) had 2.3 and 1.3 times higher recalcitrant C over the CT *viz.* CT(RW) and CT(RWM)+R(M) and partial CA *viz.*, CTR-ZTW+R(R) and CTR-ZT(WM)+R(RM) respectively. Organic-N content was also higher with CA than that with CT and partial CA by 37-45% and 30-32% respectively. On average, after five years of experimentation with CA, stabilization of N in non-hydrolysable form was increased by 62% and 56% compared to CT and partial CA, respectively. Besides, hydrolysable organic-N content was also improved with conservation practices (CA >1.3-1.4 CT; CA >1.2 partial CA). Practicing CA systems typically develop a highly stratified vertical distribution of SOC with time. It has been reported that significant increase in SOC with CA systems are usually confined to the surface 30 cm and even more typically to the surface soil (0-15 cm). Gal *et al.* (2007) also reported a stratified accumulation of both SOC and total-N over a period of time. Interestingly, the proportionate contribution of hydrolysable N to organic-N was not significantly changed with the intensity of CA though it influences the sequestration of N in non-hydrolysable pool. Results thus indicated that CA is a useful alternative management practice in enhancing C and N stabilization in soils.



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## ARTICLE 3

### **Assessing Zn induced Fe depletion in processed foods made up of Zn fortified cereal grains**

#### **Introduction:**

Dietary deficiencies of Zn and Fe, affecting over two billion people and causing a loss of 63 million life-years annually, are a serious global public health issue (Myers *et al.*, 2014). To overcome the problem of Zn deficiency, agronomic biofortification of Zn in cereals is advocated (Zou *et al.*, 2012; Cakmak, 2008). Zn-Fe antagonism through such application of Zn in cereals may be obvious due to competition of these two elements through same transport channel in plant body (Giordano and Mortvedt, 1972; Palmgren *et al.*, 2008; Saha *et al.*, 2015). Moreover, Zn and Fe in cereal grains are prone to loss during different processing techniques adopted to prepare foods. Zinc induced Fe depletion is expected to become more acute in processed food products made up of Zn fortified cereal grains. Our experiment was aimed to assess the loss of Fe from Zn fortified grains of rice, wheat and maize during processing to prepare consumable food products

#### **Materials and methods:**

The experiments were conducted in the university research farm at Gayeshpur (22°58' N, 88° 29' E) under hot and humid climate with annual average rainfall of ~1480 mm and maximum and minimum temperatures of 36.2 ± 2.0°C and 12.5 ± 1.0°C, respectively. The seeds of all the ten cultivars each of wheat (at 22.5 cm x continuous), rice (at 25.0 cm × 25.0 cm, 21 days old seedlings), maize (at 60 cm × 30 cm) were sown/transplanted with 6 treatments of Zn in plots of 30 m<sup>2</sup> (6.0 m × 5.0 m) with three replications for two consecutive years. Wheat was raised as *Rabi crop* (Date of sowing: 15th November), Rice was raised as *Kharif crop* (Date of transplanting: First week of July) and Maize was raised as pre- *Kharif crop* (Date of Sowing: First week of April).



**Table 1: Properties of the experimental soil**

Location	Soil pH	Oxidizable organic carbon g kg <sup>-1</sup>	Plant extractable Macronutrients (kg ha <sup>-1</sup> )			Plant extractable Micronutrients (mg kg <sup>-1</sup> )	
			N	P	K	Zn	Fe
Gayeshpur (University Research farm)	6.5	6.9	415.0	20.0	165.0	0.6	215.8

**Table 2: Cultivars of three cereals used in the experiment**

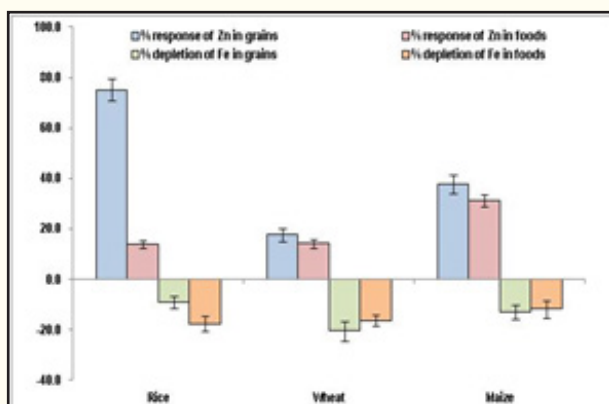
Cereals	Cultivars used
Rice (Kharif season)	Gobindo Bhog, Radhunipagal, Badsha Bhog, KRH 2, PHB 71, Pro Agro, GB 1, Satabdi, Lalat, MTU 7029)
Wheat (Rabi season)	UP 262, Sonalika, DBW 39, HD 2733, K 0911, PBW 343, CG 1006, HI 1563, GW 433, WH 1123
Maize (Pre-Kharif season)	900M Gold, DKC 9081, All Rounder, Double, Prabal, DKC 7074, NMH 123, BN 103, BN 101, Super 36

Six different Zn application protocols were used on the cultivars of wheat and rice along with standard management practices. Two doses of FYM i.e. 0 t/ha and 5 t/ha was also applied for each Zn treatment. All the harvested grains were further processed (debranning and cooking for wheat and maize grains; Hulling, milling and cooking for Rice/Paddy grains) and analyzed for Zn and Fe. Results of the experiments were analysed based on a strip-strip design, with the help of SPSS software (SPSS 14.0).

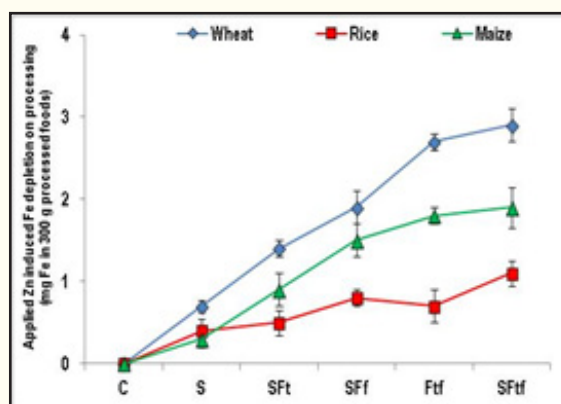
After homogeneity trials with two consecutive rice without any fertilization, soil samples were collected (0-0.2 m layer) from the experimental fields (two adjacent Zn-deficient fields were chosen for consecutive years to avoid residual effect of any applied Zn, for each of the three sites) on primary land preparation for analysis of pH (soil : water:: 1:2.5), oxidizable organic carbon, 0.32% KMnO<sub>4</sub> extractable N, 0.5M NaHCO<sub>3</sub> (pH 8.5) extractable P and 1.0M CH<sub>3</sub>COONH<sub>4</sub> (pH 7.0) extractable K (Jackson, 1973) and 0.005M DTPA extractable micronutrients viz., Zn and Fe (Lindsay and Norvell, 1978) following standard methods. The plant samples were thoroughly cleaned by winnowing through hot air and oven-dried (45°C), processed and dry-ashed (0.5 g at 550°C in a muffle furnace for four and half hours) and dissolved in 2.0 M HCl solution for analysis of Zn and Fe using atomic absorption spectrophotometer (GBC Avanta, model no. 912).

**Table 3: Zinc treatments applied**

Symbol for each application protocol	Application protocol in details
C	No application of Zn (control)
S	Basal application @ 5.0 kg Zn ha <sup>-1</sup> through ZnSO <sub>4</sub> .7H <sub>2</sub> O
SFt	Basal application @ 4.5 kg Zn ha <sup>-1</sup> +one foliar application at maximum tillering @ 0.1% aq. solution of Zn (660 litre ha <sup>-1</sup> )
SFf	Basal application @ 4.5 kg Zn ha <sup>-1</sup> +one foliar application at flowering @ 0.1% aq. solution of Zn (660 litre ha <sup>-1</sup> )
Ftf	Foliar application twice at maximum tillering and flowering @ 0.1% aq. solution each of Zn (1320 litre ha <sup>-1</sup> )
SFtf	Basal application @ 4.5 kg Zn ha <sup>-1</sup> +foliar application twice at maximum tillering and flowering each @ 0.05% aq. solution of Zn (1320 litre ha <sup>-1</sup> )



**Fig 1: Zn response and Fe depletion in cereal grains and processed foods**



**Fig 2: Zn induced Fe depletion in foods made up of Zn fortified grains**

### Results and discussion:

Our experiment revealed that Zn induced Fe depletion was obvious both in the harvested grains of all the three cereals. Such depletions of Fe were 8-10% for 70-80% response of Zn in rice grains, 18-20% for 15-20% Zn response in wheat grains and 10-15% for 35-40% Zn response in maize grains (Fig 1). We, further, found that such antagonistic behaviour also persists in processed food products made up of harvested grains of those cereals. It was also obvious that the Zn induced Fe depletion was more acute when Zn was applied through soil and two foliar (S<sub>f</sub>) (Fig 2). A significant increase in Fe loss from Zn fortified grains over control during processing indicates that applied Zn somehow creates a barrier to Fe diffusion into seed endosperm. Hence, the native distribution of Fe in different layers of cereal grains is altered by application of Zn. The net effect was a depletion of 0.7, 1.9 and 1.8 mg of Fe due to an enrichment of 0.5, 1.0 and 3.0 mg of Zn in 300 g of cooked rice, and flat breads of wheat and maize prepared from such Zn fortified grains. The processed food products made up of rice grains ended with a little amount of added Zn possibly due to three steps processing including hulling, milling and cooking. Wheat loses maximum amount of Fe i.e. 1.9 mg in 300 g flat breads on processing followed by maize (depletion of Fe was 1.8 mg) and rice (0.7 mg). Such loss of Fe on processing also depends upon native Fe reserve of cereal grains. Wheat and maize have higher native Fe reserve in harvested grains than rice. Thus, rice loses minimum Fe as compared to wheat and maize on processing to consumable food products.

### Conclusion:

Application of Zn in cereals caused Fe depletion in cereal grains and such loss also sustains in processed food products. The method and time of Zn application influence this antagonistic relationship between Zn and Fe. Such Zn induced Fe depletion also depends upon the native Fe reserve of the harvested cereal grains; wheat showing maximum followed by maize and rice.

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## ARTICLE 4

### Sensitivity of extractants and balance of sulphur in soils under long-term experiment

#### Introduction:

Sulphur is recognized as the fourth major essential nutrient severely limiting crop production after nitrogen, phosphorus and zinc in India. Over the last decade sulphur (S) deficiency was recognized as a constraint to crop production all over the world (Scherer, 2009). The problem appears to be more acute in India where 40.5% cultivated area is reported to be deficient in S (Shukla and Behera, 2019). Sulphur occurs in soil in different pools differing in solubility and thus plant availability. Water soluble, exchangeable and adsorbed pools are presumed to be readily available, while organic and insoluble inorganic pools are potentially plant available. Estimation of these pools of S and their transformation provide an insight of S availability in soils for its sustainable management for crop production. A few simple extractants are used across the world for assessing S content in soils, the most commonly used extractants are 0.15%  $\text{CaCl}_2$  and  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ ; occasionally others namely  $\text{KH}_2\text{PO}_4$ , Morgan's reagent, HCl and  $\text{NaHCO}_3$  are also advocated. Conventionally, the suitability of these extractants is judged by drawing correlations between their extractable amounts in soils and the response of yield and concentration of S in plant tissues on S application (Rajkonwar *et al.*, 2016). However, in the present study, we employed some additional useful criteria for a comprehensive selection of the extractants. Efficient management of S in soils is fundamental for improving its nutrition of crops. Quantifying S budget, namely the amount entering and leaving a given system, is thus the first step towards a better S management in soils for crops. Sulphur leaching and crop uptake are the largest outputs of S in agro-ecosystems, and the inputs of S from different sources, i.e. fertilizers, crop residues, and animal manure, are important for matching S supply to S demand (Hoang *et al.*, 2020). The present study was, therefore, undertaken to i) screen the most sensitive extractant; and ii) prepare a balance sheet of S for a 30 years old long-term experiment.

#### Material and Methods:

Soil samples were collected from a long-term field experiment on nutrient management practices at Solapur ( $75^\circ 32'$  east longitude and  $17^\circ 51'$  north latitude at 480 m mean sea level) centre of the Indian Council of Agricultural Research (ICAR)-All India Coordinated Research Project for Dryland Agriculture in Maharashtra State of Western India in 1987 with post-monsoon sorghum (*Sorghum bicolor* L. Moench, cv. M 35-1) as the test crop. The treatments comprised of i) no application of organic, inorganic or their combination of N - control, ii) 25.0 kg N  $\text{ha}^{-1}$  as urea (UR), iii) 25.0 kg N  $\text{ha}^{-1}$  through crop residue (CR), iv) 25.0 kg N  $\text{ha}^{-1}$  through farmyard manure (FYM), v) 25.0 kg N  $\text{ha}^{-1}$  through Leucaena loppings (GM), vi) 25.0 kg N  $\text{ha}^{-1}$  through CR + 25.0 kg N  $\text{ha}^{-1}$  through GM, vii) 25.0 kg N  $\text{ha}^{-1}$  through CR + 25.0 kg N  $\text{ha}^{-1}$  through urea, viii) 25.0 kg N  $\text{ha}^{-1}$  through FYM + 25.0 kg N  $\text{ha}^{-1}$  through urea, and ix) 25.0 kg N  $\text{ha}^{-1}$  through GM+ 25.0 kg N  $\text{ha}^{-1}$  through urea. The recommended dose of fertilizers was N @ 50kg urea, P @ 25kg  $\text{P}_2\text{O}_5$   $\text{ha}^{-1}$  to all treatments, FYM @ 4.5t  $\text{ha}^{-1}$ , CR @ 5.1 t  $\text{ha}^{-1}$  and GM @ 1.1t  $\text{ha}^{-1}$  was applied. The extractants used for S availability were- 0.15% Calcium chloride ( $\text{CaCl}_2$ ) CC, Morgan's reagent-MR, Mono calcium phosphate [ $\text{Ca}(\text{H}_2\text{PO}_4)_2$ ] MCP, Hydrochloric acid (HCl) and sodium bicarbonate ( $\text{NaHCO}_3$ )- SBC. Sulphur was determined by turbidimetric method from the extracts. Total S was determined by CHNS analyzer. The amount of the added S retained, utilised and lost was calculated as follows:

- a) S retained (%) =  $\text{Total S (Treatment-Control) / Applied S} * 100$
- b) S utilised (%) =  $\text{Total uptake (Treatment-Control) / Applied sulphur} * 100$
- c) S lost (%) =  $[\text{S applied} - \{(\text{S retained} + \text{S utilised}) \text{ over control}\}] / \text{Applied S} * 100$

To test the sensitivity and suitability of the extractants for different purposes, following three criteria were evaluated:

- i) Responsiveness of different extractants to added S in soils computed through linear regression model between S addition ( $\text{kg ha}^{-1}$ ) and S extracted by the extractants compared ( $\text{kg ha}^{-1}$ );
- ii) Value of correlation coefficients computed between S extracted by the extractants and S uptake of crop
- iii) The extent of variability among the extractants was calculated from the standard deviations (SD) of the amount of S extracted by the extractants used;

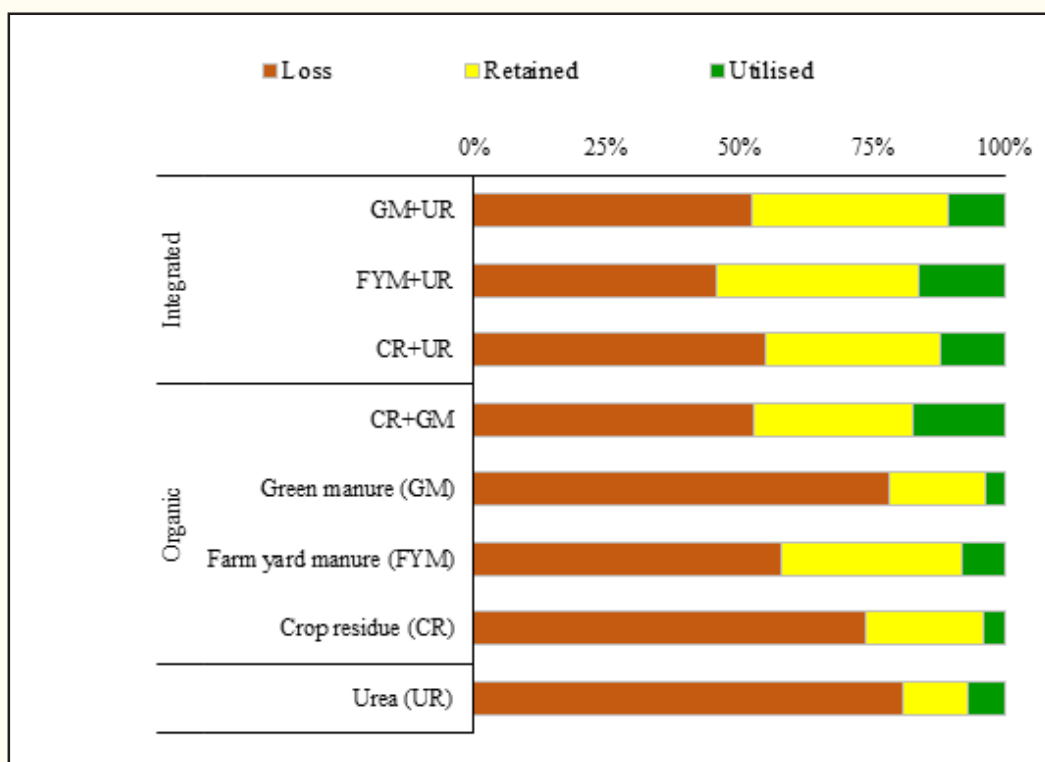
**Results and discussion:**

We calculated the responsiveness of the extractants to S addition by linear regression model (Ketterings et al., 2011) computed between the extractability of S in soils and addition of S through fertilizers and organics, and found MCP and CC excelled over the others because only these two extractants showed significant correlations (Table 1). Other models (i.e. quadratic, polynomial) were also run to improve the R<sup>2</sup> values, but with little success; and thus result of the linear regression model was used for the selection. The second criterion was the conventional one where the extractable S amount in soil was correlated with yield and S concentration/uptake of the crop. Among the extractants, MCP, HCl and MR showed the highest correlation values. The extent of deviation (SD) was highest with MCP (9.8) followed by PDP (9.5) and MR (8.4). The higher SD value is preferred as it is more sensitive to perturbations and management practices. Based on all these criteria of sensitivity, we found MCP suitable for assessment of available S in the experimental soils.

**Table 1: Sensitivity of different extractants to added S in soils computed through three different criteria**

Criteria	(i)		(ii)	(iii)
Extractants	Probability (P<0.05)	R <sup>2</sup>	Correlation with uptake	SD
Ca(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> (MCP)	0.038 (S)	0.481	0.886**	9.8
CaCl <sub>2</sub> (CC)	0.040 (S)	0.431	0.705**	4.9
KH <sub>2</sub> PO <sub>4</sub> (PDP)	0.053 (NS)	0.436	0.666**	9.5
HCl	0.081 (NS)	0.373	0.620**	8.0
NaOAc-HOAc (MR)	0.103 (NS)	0.334	0.599*	8.4
NaHCO <sub>3</sub> (SBC)	0.119 (NS)	0.311	0.356	7.5

S= significant, NS= non-significant



**Fig.1. Sulphur balance for the studied soil-crop system with different management practices for the 30-y period**



While calculating S balance for the studied soil-crop system, we observed, on average, ~28% (11.6 to 38.2%) of the applied S was leftover (retained) in the soils, 10% (7.1 to 17.5%) was utilised by the crop and 62% (45.5 to 81.4%) was lost through different processes such as leaching, runoff (Fig.1). Such loss of applied S was maximum with inorganic (81.4%) followed by organic (65.7%) and integrated (51.1%) treatments. The latter treatment thus curbed S loss by additional 14.5 and 30.3% of the applied amount over those with the organic and inorganic treatments, respectively. This was possibly due to the observed higher yield associated S uptake ( $3.5 \text{ kg ha}^{-1}$ ) and increased soil S retention (35.9%) with the integrated treatments. The loss of S from our soils was curbed under integrated and organic treatments with increased amount of organic C, and oxides and hydroxides of Fe and Al. Both the integrated and organic treatments had higher organic C, and therefore S retention by soils under those treatments was higher. Retention of S was also a function of change in pH, organic C, oxides and hydroxides of Fe and Al and clay content in soil, like those for loss, but opposite. Integrated application of organics with inorganics significantly increased the extractable S content in soils.

### **Conclusion:**

Thus it is concluded that among the six extractants mono calcium phosphate (MCP) was the most sensitive one for assessment of available S in the experimental soils. Integrated management practices particularly with FYM excelled both in retention and utilization of S, curbing its losses from the system over the organics and inorganic ones and recommended for promotion in Vertisols suffering from S deficiency.

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## ARTICLE 5

### How well do the Rice Simulation Model (ORYZA2000) able to reproduce realistic rice yield over old alluvial Zones of West Bengal

#### Introduction:

After China, India is the world's second-largest rice producer. With an average yield of  $3.57 \text{ t ha}^{-1}$ , India produces roughly 152.6 million tonnes of rice from 42.5 million hectares (FAOSTAT, 2014). Rice is grown all over the world with a focus on: i) increasing grain yield, ii) lowering production costs and iii) limiting pollution threats to the environment (Koutroubas and Ntanos, 2003). Crop growth models can be used to forecast crop performance in agro-climatological settings where the crop has never been grown previously or cultivated under ideal conditions. Crop models can also be used to assess the effects of climate variability on yield and to investigate potential solutions for dealing with it (Akponikpea *et al.*, 2011). ORYZA 2000 has been calibrated and validated in 15 places across Asia for nearly 18 popular rice varieties. The potential of ORYZA2000 to estimate rice yield performance, particularly under diverse nitrogen dosages and irrigation regimes in the Malda region, has not been examined. The purpose of this study is to see how well it can simulate the yield characteristics of *Boro* rice under nitrogen and irrigation management in the Malda district in the Old Alluvial Zone of West Bengal (Majumder and Das, 2018).

#### Materials and Methods:

A field experiment was conducted with *Boro* rice variety MTU-1010 during 2019-20 in Block Seed Farm, Malda Krishi Vigyan Kendra, Ratua, West Bengal, which is located at  $25^{\circ}19' \text{ N}$  latitude and  $87^{\circ}92' \text{ E}$  longitude.

The field trial used a three-replication randomised block design with four nitrogen doses:  $N_1$  ( $150.0 \text{ kg N ha}_1$ ),  $N_2$  ( $112.5 \text{ kg N ha}_1$ ),  $N_3$  ( $75.0 \text{ kg N ha}_1$ ) and  $N_4$  ( $120.0 \text{ kg N ha}_1$ ) as well as three irrigation regimes:  $I_1$  (constant ponding of 5 cm of water throughout),  $I_2$  (irrigation applied one day after complete disappearance of water), and  $I_3$  (irrigation applied two day after complete disappearance of water). The following four main phenological stages of rice have been added into the ORYZA 2000 based on the thermal energy requirements of rice at various developmental stages as measured by growing degree

days (GDD) based on daily temperature change: i) basic vegetative phase or juvenile phase, from emergence (development stage [DVS] = 0) to start of photoperiod-sensitive phase (DVS = 0.4), ii) photoperiod-sensitive phase, from DVS = 0.4 until panicle initiation (DVS = 0.65), iii) panicle development phase, from DVS = 0.65 until 50% of flowering (DVS = 1.0), and iv) grain-filling phase, from DVSS = 0.4 until panicle initiation (DVS = 0.65). Two distinct programmes (DRATES and PARAM) were used to calibrate the ORYZA 2000 plant characteristics using the field data. We executed those methods for the current experiment utilizing initial values of development coefficients for various parameters and updated them with simulated values. The graphical analysis and statistical measures were completed in accordance with Jing *et al.* (2007). Total biomass, biomass of individual organs, crop N uptake, and N uptake of individual organs have all been simulated and quantified and compared graphically. The fundamental input data files contain all of the needed input factors, such as weather, crop, and experimental data from the field experiment. In summary, the developmental rate constants were calculated using the DRATES programme, as shown in Table 1. All of these variables were then added to the crop data file, and the software was ran once more to generate the simulated results.

#### Results and Discussion:

The nitrogen dose of  $150 \text{ kg ha}^{-1}$  ( $N_1$ ) combined with continuous ponding of 5 cm water level throughout the season produced highest grain production of  $6.83 \text{ t ha}^{-1}$  at 14% moisture level, while the combination of  $N3I3$  produced the lowest yield. The plants were exposed to high temperatures, particularly during the later stages of growth (Fig 1), such as flowering



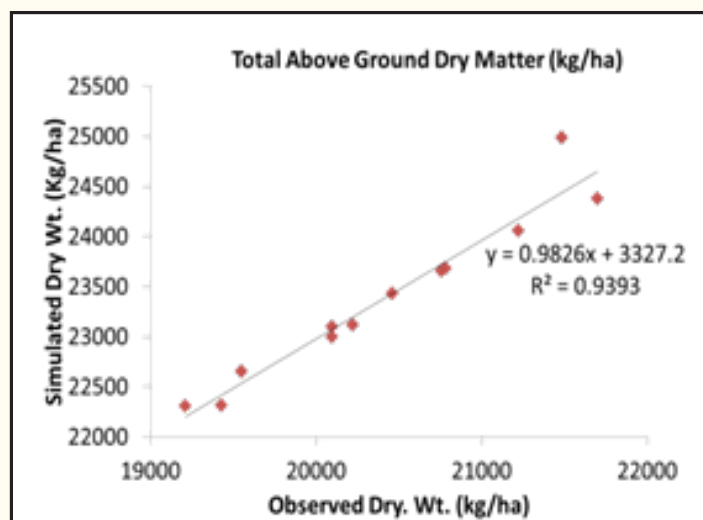
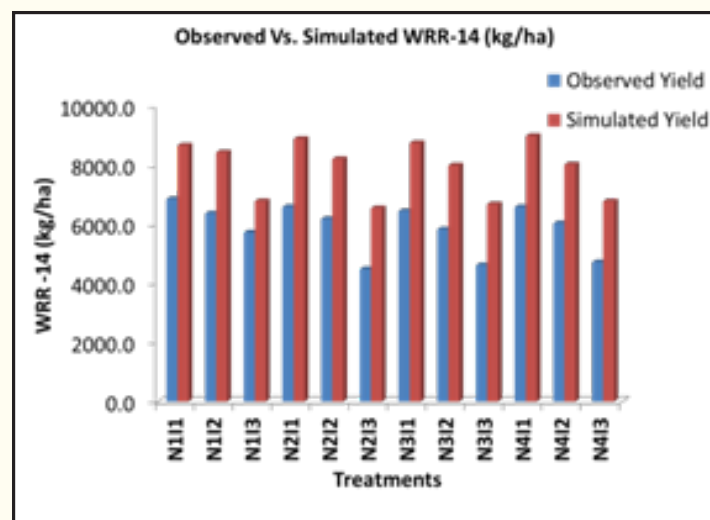


(95 days after sowing), resulting in low yields ( $4.4 \text{ t ha}^{-1}$ ). Total dry weight of storage organs (WSO), total above ground dry matter (WAGT), and accumulated nitrogen concentration all yielded similar results (ANCR). Throughout the season, however, no significant variations in yield metrics were recorded under the conditions of  $112.5 \text{ kg ha}^{-1} (\text{N}_2)$  with continuous ponding water and  $120.0 \text{ kg ha}^{-1} (\text{N}_4)$  with continuous ponding ( $\text{I}_1$ ). In both cases, the yield was around  $6.5 \text{ t ha}^{-1}$ . The model-simulated findings were compared to the experimental results obtained from field experiment to assess the ORYZA 2000's performance. It was discovered that the  $\text{N}_4\text{I}_1$  combination provided the

**Table 1: Developmental rate coefficients at various developmental stages**

Development Coefficient	Descriptions	Developmental Rate
DVR	Development rate constant at basic vegetative phase (BVP)	0.000772
DVRI	Development rate constant at photoperiod-sensitive phase (PSP)	0.000757
DVRP	Development rate constant at panicle formation phase (PFP)	0.000785
DVRR	Development rate constant at grain-filling phase (GFP)	0.001785
TSTR	Temperature sum for phenological development at transplanting ( $^{\circ}\text{Cd}$ )	202.55
TSF	Temperature sum for phenological development at flowering ( $^{\circ}\text{Cd}$ )	374.8
TSM	Temperature sum for phenological development at maturity ( $^{\circ}\text{Cd}$ )	1935.7

maximum rice yield of  $8.9 \text{ t ha}^{-1}$ , whereas the  $\text{N}_2\text{I}_3$  combination, in which irrigation was administered after 2 days of total water disappearance, produced the lowest yield of  $6.5 \text{ t ha}^{-1}$ . Because pre-monsoonal rainfall is unpredictable during the *Boro* season, irrigation is a necessity for ensuring paddy output. The linear relationship between observed and simulated yield components of total above ground dry matter, total dry weight of storage organs, and nitrogen content is shown in Fig. 1(a-d), indicating a strong dependency as evidenced by their high positive correlations of  $R^2=93.3$ ,  $R^2=97.7$ , and  $R^2=83.1$  for total above ground dry matter. The RMSE calculated for the above parameters, grain yield, total dry weight of storage organs, total above ground dry matter, and nitrogen accumulation, were 2049.8, 2092.8, 2985.7, and 17.1, respectively, indicating that the model can be used to predict rice yield satisfactorily if the model is fine-tuned to remove the initial biasness.



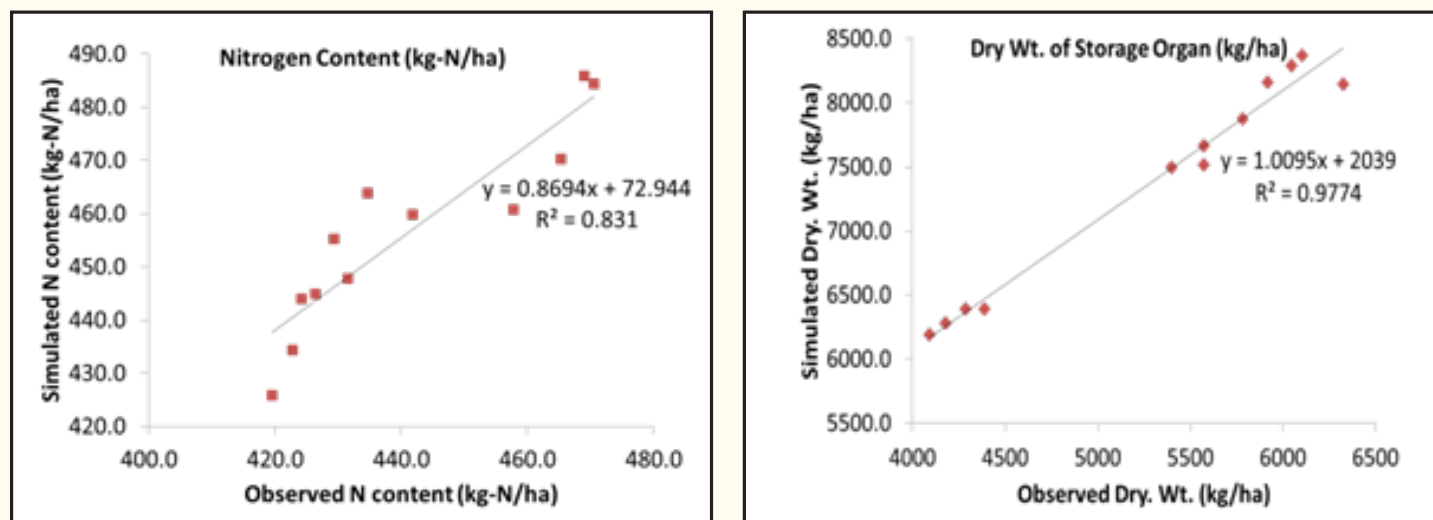


Fig 1 (a-d): Relationship between simulated and observed (a) grain yield, (b) dry wt. storage organs, (c) total above ground matter and (d) accumulated nitrogen concentration.

### Conclusion:

In general, the model was able to fairly accurately reproduce the observed yield components, however it did have a tendency to overestimate. The model successfully reproduced the influence of nitrogen doses under various irrigation schedules, showing that it may be used to improve fertiliser application doses and irrigation efficiency in any location after calibration.

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## ARTICLE 6

### Conservation agriculture influences organic carbon pools and quality of soils

Indian agriculture witnessed a drastic change in crop production during green revolution. But unfortunately, due to indiscriminate use of agrochemicals and imbalanced fertilization, it resulted in unsustainable productivity, environmental pollution and decline in soil organic matter storage under high intensity agriculture in the post-green revolution era which has been a matter of great concern today. Sustaining the productivity at higher level is the key issue in Indian agriculture to meet the demands of food and fibre for the ever-growing population. In order to overcome such problems, a new technology came to the fore called 'Conservation Agriculture'(CA).

Plow-based intensive agriculture has exacerbated the problems of accelerated erosion, and rapid oxidation of soil organic carbon leading to deterioration of soil quality and subsequently the environmental quality (Lal, 1999). Conservation agriculture reverses the soil degradation processes through enrichment of soil organic carbon, accelerating carbon sequestration and supporting sustainable crop production. To evaluate the impact of conservation agricultural practices on allocation of soil organic carbon into pools of varying stability and quality, a study was conducted with a rice-wheat cropping system in alluvial soil of the eastern Indo-Gangetic plain. For this study, we hypothesised that under restricted tillage environment, conservation agriculture promotes allocation of soil organic carbon into different pools of varying stability and improves soil quality through carbon enrichment.

The experimental site at Pusa consists of five treatments of varying intensity of conservation agricultural practices namely control (conventional tillage), partial CA (conventional followed by zero tillage), zero tillage without residue (zero tillage-R), zero tillage with brown manuring (zero tillage + BM) and zero tillage with residue (zero tillage + R). Soil samples are collected from three different depths (i.e., 0-5 cm, 5-15cm and 15-30cm) to study carbon allocation. Collected soil samples are analysed for different pools of carbon following standard protocols as proposed by Chan *et al.*, 2001.

The result of the present study revealed that, irrespective of soil depths, both labile and non-labile carbon in soils under the treatment receiving zero tillage with residue were significantly higher than that of conventional tillage system which was presented in Fig.1. The treatment receiving zero tillage practices with residue had a higher amount of both labile (about 108 %) and non-labile carbon (about 132 %) than conventional system. The zero tillage with residue treatment also excelled the treatment receiving only zero tillage practices without any residue, having about 15% and 33% of higher labile and non-labile carbon respectively. Limited tillage environment along with crop residue enhanced microbial diversity in the rhizosphere thereby accelerating the microbial-driven decomposition of soil organic matter which improved allocation of both labile and non-labile carbon in soils (Doran *et al.* 1998). The influence of CA on quality of organic matter was illustrated in Fig.2. The lability index recorded a decrease under the CA system suggesting allocation of carbon in stabilized pools. On the other hand, there was an increase in recalcitrant index under CA system reflecting the global warming curbing ability of CA through enhanced carbon sequestration.

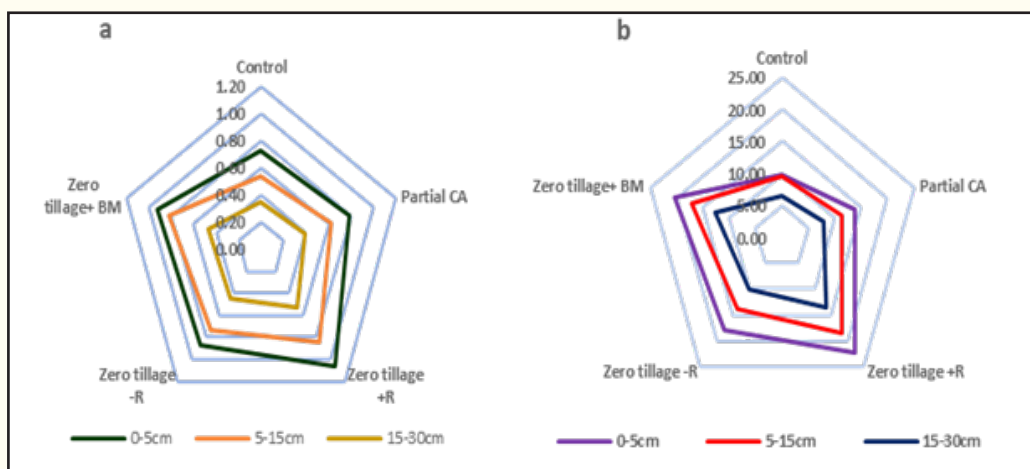
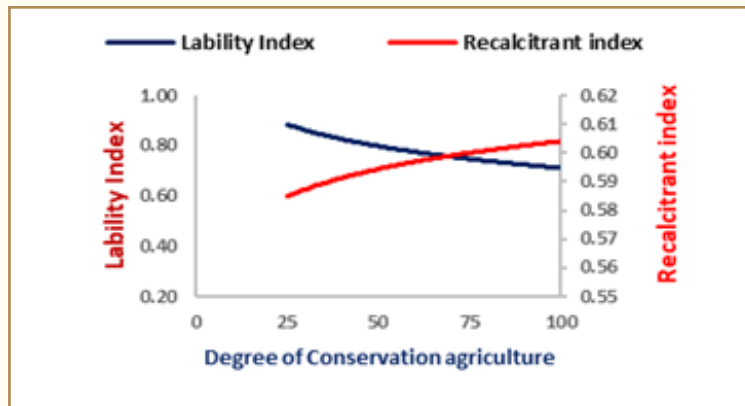


Fig.1. Impact of conservation agriculture on vertical distribution of (a) labile carbon and (b) non-labile carbon



**Fig. 2. Impact of conservation agriculture on quality of organic matter**

From the results, it was inferred that CA practices with minimum disturbance, residue retention and crop diversification had an important role in upkeeping health of soil through an enrichment in organic carbon content in soils. Hence, the treatment receiving zero tillage with residue is considered as the best land management practice for improving soil carbon.

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