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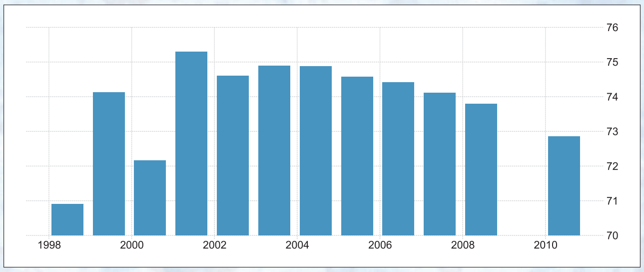
# Fertilizers and Environment News

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

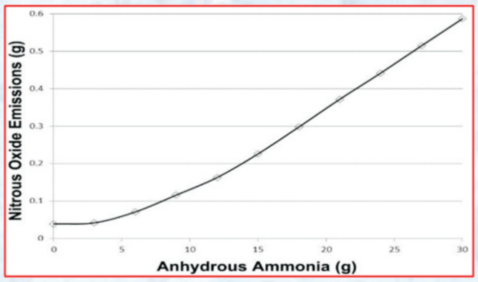
## From President's Desk

### Nitrous oxide emission is most lethal to global warming

In the earlier issue I discussed on significance and methods to reduce carbon footprint in an agricultural field to offset global warming phenomenon. Soil is an important reservoir of carbon which means that relatively small changes in the amount of carbon stored in soil could have significant effects on net greenhouse gas emissions like $CO_2$, $CH_4$ and $N_2O$. On a 100-year time frame methane has been found to be 25 times more potent and nitrous oxide 300 times potent than $CO_2$ for its impacts on global warming. Thus, $NO_2$ is most lethal to global warming. In India, the agricultural $N_2O$ emission resulting mainly from fertilizers (synthetic and animal manure), crop residue burning and other field waste management, and animal waste management, accounted for 72.84 % of total (according to World Bank collection of development indicators) as of 2010 (see picture to the right). Total nitrous oxide emission as of 2012 was estimated as nearly 239,755 thousand metric tons of $CO_2$ equivalence rising from 184,314 thousand metric tons in 1993, thereby increasing at an average rate 1.42 % annually. Future $N_2O$ emissions in 2030 are projected to reach 0.81 Tg (reference scenario), 0.69 Tg (medium mitigation scenario) and 0.6 Tg (strong mitigation scenario). The European Commission released the global nitrous oxide emission data increasing steeply from 2,225,930 in 1976 to 3,53,742 thousand metric tons of $CO_2$ equivalence.




Steps have been undertaken to mitigate $N_2O$ emission, notable of which is the robust and scientifically developed and tested down up to eco-district level protocol from Canada, called as Nitrogen Emission Reduction Protocol (NERP) based on 4R Nutrient Stewardship Program (https://fertilizercanada.ca/wp-content/uploads/2016/03/The-Nitrous-Oxide-Emission-Reduction-Protocol-A-Canadian-Case-Study.pdf). It postulates that while all addition of nitrogen to cropping systems can drive up $N_2O$ emissions (see picture to the right), nitrogen fertilizer is the main driver of yield in modern high production systems. Through careful selection of nitrogen fertilizer source, rate, timing, and placement practices, the $N_2O$ emissions per unit of crop produced can be substantially reduced, in some cases by up to half. Equally important, the practices that reduce $N_2O$ emissions also tend to increase nitrogen use efficiency and the economic return on fertilizer inputs. In India, such development protocols are at different stages based on rate and timing of application of fertilizer and organic manures including Municipal Solid Waste. Interestingly, very recently it has been observed that some soil bacteria are effective in absorbing nitrous oxide gas emitted due to fertilizer application to soil. A bet-hedging strategy for denitrifying bacteria curtails their release of $N_2O$ (https://www.pnas.org/content/pnas/115/46/11820.full.pdf). It is projected to be effective to mitigate global warming.




Source: Brevik (2012).
Also see University of East Angila, at
DOI:10.1073/pnas.1805000115

Content:

In this issue, there are four articles. Prof. Bijay-Singh deals with optimizing fertilizer nitrogen application for improving NUE in the background of climate change scenario in South Asia. Dr. C. L. Acharya and his associate deals with crop residue burning contributing to emission of different gases, their impacts on global warming, suggest practising conservation agriculture (CA) to combat the menace and the role of the government towards it. The role of CA on aggregate-associated N and its impacts on $N_2O$ emission and global warming potential, though not substantiated through their own data under maize-wheat rotation, has been discussed based on a 5-year field trial by Dr. Bhattacharya and co-workers. Dr. R. K. Gupta and co-workers, on the other hand, following a threadbare analysis of the present 'National Soil Health Scheme' presented a new holistic approach in conceptualising 'soil health' and suggested a new assessment protocol, which, I believe, will open a new era of our understanding of the phenomenon.

**HSSen**
*President*

## NEWS

### Executive Committee Meeting of the Society

### Date: November 20, 2018

### Venue: BCKV

Executive Committee (EC) meeting was held on November 20, 2018 at 3.00 PM at the Department of Agricultural Chemistry and Soil Science, BCKV, Mohanpur.

The meeting was chaired by Dr. H. S. Sen, President of SFE. Salient points/recommendations, which emanated out of the meeting, are as below,

1. Dr. Sen advised to make National and International Bank of Authors for inviting of articles for the Newsletter. All EC members were requested to act accordingly at individual levels and prepare such bank of authors along with their fields of specialization and communicate the same within one month.
2. Dr. Dibyendu Sarkar, Treasurer was requested to expedite the process of more fixed deposits in small amounts as per norms of the bank.
3. The audit papers ending March 2018 may be submitted within 15 days. The papers related to Return for IT may be submitted within 1 month of the receipt of the audit papers duly completed and signed by the auditor.
4. All backlogs for renewal of registration should be updated within March 2019.
5. It was discussed at length that the possibility to receive fund for meeting the expenditure for publishing the newsletter may be explored. At present, the annual expenditure is about Rs. 1 lakh. However, there was no conclusion in this meeting after the Secretary said that ICAR does not provide fund for newsletters. It was suggested that other avenues may be explored. Initiation of a journal instead of a newsletter could be one such possibility to be able to attract fund from ICAR towards publication cost.
6. It was decided in the meeting that Dr. Dipankar Ghorai, Dr. Narayan Chandra Sahu and Dr. Siladitya Bandyopadhyay will make a note regarding initiation of a journal for the Society. They may prepare a joint note and submit at the earliest.
7. The Secretary was requested to kindly explore registering the society/newsletter with NITI Aayog through NGO Darpan website by March, 2019.
8. Dr. H.S. Sen made a proposal that he may be relieved from the Presidentship of the Society because of ill health. But, the EC members unanimously decided that Dr. Sen may continue as the President of the society and guide it so long his health permits.
9. Detailed activities for rest of the year (2018-19) were chalked out.

## ARTICLES

### ARTICLE - 1

### Optimizing fertilizer nitrogen management in emerging climate change scenarios in South Asia

Even with all the efforts being made through international negotiations to reduce greenhouse gas emissions, the world has become warmer from 1850–1900 to 1986–2005 by 0.61°C (IPCC, 2014). In South Asia too, increasing annual mean temperature is likely to increase further. Predicting and mitigating the impacts of climate change on agroecosystems are going to be the greatest challenges in the present century.

Studies pertaining to the effects of climate change on soil processes and properties are now becoming available and it is becoming increasingly clear that climate change will impact soil organic matter dynamics, including soil organisms and the multiple soil properties that are tied to organic matter, soil water, and soil erosion. Current nutrient management recommendations for different crops are based on an understanding of crop-specific needs for achieving optimum yields as well as nutrient supplying characteristics of the soil. The big challenge ahead is to know as to what extent our existing knowledge will remain useful under a changed climate. Possibly, an assessment of the climate change factors to influence the physiological efficiency of nutrient use within the plant and to alter the availability of nutrients in soil and their transport through soil and across root membranes should be helpful in understanding fertilizer N management under emerging climate change scenarios.

#### *Emerging climate change scenarios in South Asia*

The Intergovernmental Panel on Climate Change has projected that in the 21st century South Asia is going to be hit hard by climate change. Lal *et al*. (2001) performed a transient experiment with a coupled atmosphere–ocean general circulation model to study climatological features associated with intraseasonal and interannual variability in monsoon circulation over the Indian subcontinent. During winter season in the Indian subcontinent, warming is projected to be at least 4°C; during monsoon season in the summer, temperature rise may range between 2.9 and 4.6°C. An increase of 7–10% in area-averaged annual mean precipitation is projected over the Indian subcontinent by 2080s. However, a decline of 5–25% is projected in the area-averaged winter precipitation. On an annual basis, it is predicted that by 2050 there will be an increase in surface temperatures by 2.23 to 2.87°C and increase in precipitation by 5.36 to 9.34%; corresponding increases by 2080 are predicted to be 3.53 to 5.55°C and 7.48 to 9.90 %, respectively.

#### *Influence of climate change on soil processes*

Research on the effects of climate change on soil processes is still in the early stages, but some useful information has already been generated. As C and N cycles are very intimately connected to each other and both C and N are important components of soil organic matter, soil processes linked with soil organic matter dynamics and N transformations and ultimately with soil fertility are going to be strongly affected by climate change (Wan *et al*., 2011).

#### Soil organic matter decomposition

A rise in air temperature and that of the soil should lead to increased decomposition and loss of soil organic matter. According to Kuzyakov and Gavrichkova (2010), it is the accessibility and availability of soil organic matter to microorganisms that govern its losses rather than the rate-modifying climate factors such as temperature. Nevertheless, the balance of opinion seems that under the emerging warming climate change scenarios, losses of soil organic matter via decomposition are likely to exceed the gains from increased plant growth thereby leading to lowering of soil organic matter levels in the soil. The increase in plant growth due to $CO_2$ fertilization effect may not be as large as originally thought because negative effects of increasing levels of ozone and increased temperatures on plant growth may cancel out any $Co_2$ fertilization effect that does take place (Jarvis *et al*., 2010). Thus soils may actually lose organic matter as atmospheric $CO_2$ levels and global temperatures increase, creating a positive feedback system that could push temperatures even higher (Brevik, 2012). But loss of soil organic matter is bound to have negative impacts on fertilizer N use efficiency leading to need for applying higher fertilizer N doses to achieve optimum yields.

#### Nitrogen mineralization

To supply N to crop plants, mineralization is an essential step. Plant productivity is negatively affected if N mineralization in the soil is reduced. When $CO_2$ enrichment increases the soil C/N ratio, decomposing organisms in the soil need more N, which can reduce N mineralization. Nitrogen limitation of $CO_2$ fertilized plants has been reported by Hungate *et al*. (2003). Although increased temperatures stimulate N availability in the soil, the net result is reduction in decomposition of soil organic carbon (Holland, 2011). Increasing temperatures increase N mineralization (Joshi *et al*., 2006), which could have a positive effect on plant growth but there are reports that N mineralization increased due to warming in the first year but was reduced afterward (An *et al*., 2005).

**Nitrification and Denitrification**

The temperature response of nitrification is approximately bell-shaped with an optimum between 20 and 35°C (Avrahami *et al*., 2003). Denitrification is generally favoured by high availability of labile C as a source of energy and of $NO_3$ as an electron acceptor. It is favoured in poorly aerated soils and exhibits a response to temperature similar to that of nitrification. Soil moisture deficit commonly associated with different global warming scenarios reduced the activity of nitrifying bacteria by slowing diffusion of substrate supply and through cytoplasmic dehydration (Stark and Firestone, 1995). Szukics *et al*. (2010) found that increasing soil temperature from 5 to 25°C stimulated N cycling by inducing the activity of microorganisms responsible for nitrification and denitrification. The nitrification rate and $NO_3^-$ concentration increased most rapidly at the 55% water content. In the 70% water content in soils, the $NO_3^-$ pool was increasingly depleted as soil temperature increased and was almost completely depleted at 25°C.

**Ammonia volatilization**

The amount of $NH_3$-N volatilized per cropping season in South Asia averaged 37.5 kg N $ha^{-1}$; global average was 19.1 kg N $ha^{-1}$ (Pan *et al*., 2016). Most $NH_3$ emissions result from agricultural production and are expected to be extremely climate sensitive. Temperature and moisture play a key roles in determining the concentration of $NH_3$ in equilibrium with surface pools and hence in defining net $NH_3$ fluxes on diurnal to annual scales. According to solubility and dissociation thermodynamics, $NH_3$ volatilization potential follows a $Q_{10}$ of 3–4 so that it nearly doubles every 5°C (Sutton *et al*., 2013). However, due to the interaction between temperature and moisture and other factors (e.g., stomatal opening, growth dilution of $NH_x$ pools, soil infiltration, and decomposition rates), the temperature dependence of $NH_3$ emission may not always follow the thermodynamic response.

**Nutrient acquisition**

Soil moisture deficit as projected in many global warming scenarios not only impacts crop productivity but also reduces yields through its influence on the availability and transport of nutrients. Nutrient diffusion over short distances and the mass flow of water-soluble nutrients over longer distances are adversely affected by soil moisture deficit. Drought alters the composition and activity of soil microbial communities, which determine the C and N transformations that govern soil fertility and nutrient cycling (Schimel *et al*., 2007). Frequent and/or intense rainfall events associated with some climate change scenarios adversely influence nutrient acquisition by crop plants in agricultural areas with poorly drained soils which may become hypoxic (St. Clair and Lynch, 2010). Under hypoxic conditions, significant losses of N can also occur through denitrification thereby leading to reduced N acquisition by crop plants. According to Bassirirad (2000), temperature increases in the rhizosphere can stimulate nutrient acquisition by increasing nutrient uptake via rapid ion diffusion rates and increased root metabolism. But positive effects of warmer temperature on nutrient capture also depend on adequate soil moisture. For example, if under dry conditions higher temperatures result in extreme vapour pressure deficits which triggers stomatal closure, nutrient acquisition driven by mass flow will decrease (Cramer *et al*., 2009).

***Nitrogen management in crops under emerging climate change scenarios: Final remarks***

Current nutrient management recommendations for different field crops in South Asia are based on crop-specific needs and nutrient supplying characteristics of the soil. Increased N use efficiency and high nutrient retrieval and nutrient utilization have been observed in response to increased $CO_2$ level in the atmosphere (Fangmeier *et al*.,1999). However, due to decrease in plant N concentration as a result of dilution through rapid growth or because of changes occurring at the level of the photosynthetic apparatus, N yields in cereals do not increase automatically under elevated $CO_2$ concentration (Fuhrer, 2003). In contrast to the effect of elevated $CO_2$,warming tends to reduce plant N use efficiency due to increased sink limitation, especially in plants with reproductive sinks. Lam *et al*. (2012) observed that irrespective of $CO_2$ level in the atmosphere, fertilizer N recovery in wheat was higher under supplementary irrigation than under rainfed conditions. Thus, fertilizer N needs of crops like wheat under future $CO_2$ environments will be high provided these are irrigated or grown in high rainfall zones rather than in hot and dry climates. And fertilizer N application rate in a cropping systems in semiarid climates will need to be increased in proportion to the yield gains expected under future $CO_2$ environments to avoid a progressive decline in soil N.

Depending upon whether crop plants will be bigger, smaller, or similar in size when compared with today's specimens, their nutrient content and physiological efficiency will be scaled according to size. Nutrient stress has the potential to reduce growth stimulation by elevated $CO_2$ (Campbell and Sage, 2006). Based on understanding of the physiological efficiency that is specific to the crop and of the utilization efficiency that is specific to the unique combination of crop and soil, nutrient recommendations for different crops under changed climate will operate on the same premise as current recommendations. Simple, empirical models will continue to be used to translate this information from theory into practice. Thus, information pertaining to current soil fertility/plant nutrition recommendations will remain viable irrespective of climate change (Brouder and Volenec, 2008).

High-input systems with adequate fertilizer use should be more sensitive to weather changes due to lack of other limiting factors (Schlenker and Lobell, 2010). Also, high-input systems will be better able to take advantage of $CO_2$ fertilization in C3 crops while maintaining nutritional quality (Ainsworth and Long, 2005). For low-fertility systems with minimal fertilizer use, atmospheric $CO_2$ should help to maintain biomass production under drought conditions, but higher $CO_2$ is more likely to decrease protein levels without additional N inputs into the system (Taub *et al*., 2008). As large area under wheat in South Asia can be classified as high-input systems to which substantial amount of fertilizers are applied, it can be expected that these systems will be hard hit by emerging climate change scenarios. In substantial area under rice in South Asia classified as low-input system, fertilizer N doses will have to be increased to maintain protein level in grain.

At the system level, warmer conditions stimulate soil N availability through higher rates of mineralization. It may lead to increased productivity, but also to higher N losses from the system, particularly if N demand by the plant is not synchronized with N supply (Fuhrer, 2003). Therefore, ideal solution for management of fertilizer N in South Asia seems to be the need-based and site-specific nutrient management. Shifting fertilizer N management from blanket recommendations for large tracts to site-specific N management is also important because agricultural fields in the South Asian countries are typically small with high spatial variability in management practices, inherent soil fertility, crop residue management, historical fertilizer use, input of organic materials, fertilizer application method and schedule, and resources available to a farmer. In last two decades, site-specific nutrient management strategies for rice, wheat and maize has been introduced in South Asia that take into account field-to-field variability and can help increase fertilizer use efficiency more than that achieved by following blanket fertilizer recommendations. These strategies are based on the use of gadgets like optical sensors, chlorophyll meters, and leaf colour charts, and should help formulate fertilizer management practices under changing climates in the decades to come (Bijay-Singh, 2014).

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## ARTICLE - 2

## Crop residue burning a menace to soil and environmental health: Conservation agriculture - a viable option

### *Crop residue burning: the present practice*

The Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India has estimated that about 500 Mt of crop residues are generated every year and out of this 91-141 Mt of residues are burnt in the country. The rice-wheat cropping systems in north western (NW) states of India produces about 34 million tonnes of rice residues of which Punjab alone contributes about 65%. The mechanized harvesting and threshing of rice using combine harvesters is a common practice in NW India. In the process, residues are left behind the combine harvesters in a narrow strip (window) in the field. Disposal or utilization of the leftover residue in the short window of ten to twenty days for timely planting of wheat crop is a difficult task. Therefore, the farmers commonly opt for an easy way out i.e., burning of rice residue in the combine-harvested fields due to lack of access to user-friendly, cost- and time-effective options.

### GHG emission and health hazard

It is estimated that in NW states of India about 23 million tonnes of rice residues are burnt annually (NAAS, 2017). This leads to deterioration of air quality in adjacent areas resulting in various health hazards besides deterioration of soil health (Table 1).

**Table1. Release of gases and particulate matter by burning 1 tonne of rice crop residues**

| Particulate matter | $CO_2$ | Carbon monoxide | $NO_x$ | $SO_2$ | Dust |
|---|---|---|---|---|---|
| 13 kg | 1460 kg | 60 kg | 3.5 kg | 3 kg | 199 kg |

**Source:** NAAS (2017)

The black carbon emitted during residue burning warms the lower atmosphere and it is the second most important contributor to global warming after $CO_2$. The emission of high levels of $PM_{2.5}$ and $PM_{10}$ in the air causes chronic diseases like cardiopulmonary disorders with irrecoverable lung capacity or asthma in human population of NW India.

**Loss of plant nutrients**

Apart from the damage caused by air pollution through GHG emission, burning of rice residue also results in loss of soil organic matter and plant nutrients and adversely affects soil health. About 90% of N and S and 15-20% of P and K contained in rice residue are lost during burning. It is estimated that one tonne of rice residue contains about 400 kg of C, 5-7 kg N, 1-1.7 kg P, 15-25 kg K and 1.1-1.4 kg S in addition to the significant amounts of micronutrients. Total amount of N, P, K and S (NPKS) in 23 million tonnes of rice residue (currently burnt in NW India annually) is about 0.7 million tonnes N, P, K, S valued at > Rs. 10 billion. Whole of organic carbon and about 0.28 million tonnes of NPKS (equivalent to about Rs. 2.5 billion) is lost during burning.

***Conservation Agriculture (CA): a viable option***

Conceptually, CA, the practice of no-tillage, with *in-situ* retention of biomass/ crop residues as mulch, and crop rotation preferably with legumes, is being considered as a climate resilient technology for moderation of hydro-thermal regime, improving soil health, water intake into the soil profile, soil moisture conservation and enhancing nutrient and water use efficiency. Few salient characteristics of CA are briefly discussed below.

**Soil erosion**

During 4 years of study in maize-wheat system, the runoff losses during maize growing under conservation tillage plus mulch of robinea (*Robinea pseudocasia*, a leguminous tree maintained as shrub on risers of terraces in alley farming concept), and crop residues (1:1) were 7 to 19 % of the total rainfall compared to 19 to 34 % under conventional tillage (Acharya *et al*., 1993). Thus, conservation tillage with residue layer on the soil surface checks the negative factors causing soil degradation like soil erosion and runoff.

**Soil porosity, aggregation and related properties**

The no-tillage without mulch showed significant increase in the bulk density of the 0-0.15 m depth. Mulching with pine needle @ 10 $tha^{-1}$ of the no-tillage, however, prevented the compaction of the untilled layer at the surface and showed significantly lower value of bulk density in the surface (0.15 m) depth (Acharya and Sharma, 1994). A significant decrease in the bulk density and increase in the porosity under no-till than in conventional tillage has also been reported (Abid and Lal, 2008). Lal (2004) reported that conservation tillage with residue layer on the surface increased the soil aggregation more than when the residue was ploughed under.

**Soil hydro-thermal regime**

CA with retention of crop residues on the soil surface not only conserves soil moisture, increases infiltration but also moderates thermal regime (Unger, 1990; Acharya *et al*., 1998) of the soil profile. In Nigeria, a no-tillage system that left substantial residue on the surface reduced the maximum soil temperature at 5 cm depth by 11°C and 9°C in two-week old maize and soybean, respectively (Lal, 1976). During wheat growth in winter the conservation tillage with residues retained on the surface raised the minimum soil temperature by 0.5-2°C and lowered the maximum soil temperature by 0.3-2°C at 5 cm depth (Acharya *et al*., 1998), and thereby moderated the temperature regime conducive to plant growth.

**Biological activity**

The improvement in the soil hydrothermal regimes promotes soil biological activities under CA. In contrast to conventional tillage, conservation tillage results in more continuous pore system because of increase in earthworm activity (Table 2), old root channels and vertical cracks between peds (Acharya *et al*., 1998). The soil biological property most affected by tillage is SOC content. The soil organic matter content influences to a large extent the activities of soil organism which in turn influences the SOC sequestration. Earthworms, which are a major component of the soil macrofauna, are important in soil fertility dynamics as their burrowing activities aid in improvement of soil aeration and water infiltration. The fact that the population of earthworms is affected by tillage practices has been documented in a ploughless tillage review by Rasmussen (1999). Long term studies revealed a significantly higher earthworm population under no-till soil than under ploughed soil and also it was found that less intense tillage increased the activities of surface-feeding earthworms.

**Table 2. Earthworm population (number $m^{-2}$) in the surface (0-15 cm) soil layer**

| Tillage | Earthworm/$m^2$ | |
|---|---|---|
| | Sowing | Flowering |
| Mulching previous standing maize with *Lantana camara* at recession of monsoon rains and its incorporation at sowing of wheat with conventional tillage ($T_1$) | 20 | 8 |
| Same as above but sowing of wheat following conservation tillage with residue retention at the soil surface ($T_2$) | 21 | 10 |
| Farmers practice of repeated tillage after maize harvest ($T_3$)<br>LSD (P = 0.05) | 4<br>1.7 | 1<br>1.4 |
| Nitrogen (N)<br>$N_{60}$<br>$N_{120}$<br>LSD (P=0.05) | <br>17<br>17<br>NS | <br>8<br>7<br>0.9 |

**Source:** Acharya *et al.* (1998)

**Root growth**

In Alfisols of North Western Himalayas favourable effect of no-tillage with mulch on root growth was recorded compared to no-tillage (NT) without mulch in maize-wheat sequence (Acharya and Sharma, 1994). Mulching under both no-tillage and conventional tillage in silty clay loam soil significantly increased root length and rooting density of crops owing to the evident improvements in soil water, temperature and reduction in soil bulk density.

**Moisture conservation, grain yield and input use efficiency**

Acharya *et al.* (1998) reported that conservation tillage to rainfed wheat with retention of the mulch material at the surface resulted in higher profile moisture storage, which led to grain yield either equivalent to or greater than that due to incorporation of this material at sowing in conventional tillage practice (Table 3). The rainfed wheat was sown by conservation and carry-over of post-monsoon soil moisture with application of tender twigs of *Lantana camara* to previously standing maize at recession of rains and retention of this material at surface for sowing rainfed wheat under no-till. The higher grain yield under conservation tillage practice was attributed to greater root proliferation and utilization of higher amount of soil moisture stored in 0-30 cm soil layer. Superiority of conservation tillage over the conventional tillage with respect to grain yield of rainfed wheat was more pronounced at 60 kg N $ha^{-1}$ than at 120 kg $Nha^{-1}$ (Table 3). This shows that moisture conserved under conservation tillage was just optimum for more efficient N utilization at 60 kg $Nha^{-1}$ than at 120 kg $Nha^{-1}$ because of strong nutrient and water interaction in case of the former. The water use efficiency was also affected accordingly owing to strong nutrient and water interaction as stated above. Das *et al.* (2014) reported that water productivity of the cotton-wheat system in the permanent broad-bed plus residue treated plot (12.58 kg wheat grain $ha^{-1}mm^{-1}$) was 48% higher compared to conventional tillage plots.

**Table 3. Effect of conservation tillage and N on grain yield of rainfed wheat**

| Tillage | Grain yield (t/ha) | | |
|---|---|---|---|
| | Nitrogen | 1989-90* | 1990-91** |
| Conventional tillage ($T_1$) | N60 | 2.81 | 3.49 |
| | N120 | 3.27 | 4.29 |
| Conservation tillage ($T_2$) | N60 | 3.10 | 4.12 |
| | N120 | 3.38 | 4.27 |
| Farmers practice ($T_3$) | N60 | 1.63 | 2.23 |
| | N120 | 1.83 | 2.77 |
| CD (P= 0.05) | | 0.27 | 0.24 |

*5 rains of 69.5 mm in November, 5 rains of 114 mm in December, **3.4 mm rain in November, 7 rains of 262 mm in December

**Source:** Acharya *et al.* (1998)

## Soil fertility

Crop residue retained as mulch under CA adds organic matter and plant nutrients to the soil upon decomposition and thus it improves carbon sequestration. The volatilization and leaching loss of nitrogen is reduced under mulched condition. During decomposition of organic mulches soil mineral nitrogen is immobilized by microbes and thus its loss is minimized (Doran, 1980). Inclusion of legumes in the crop rotation under CA facilitates biological N fixation and improves soil fertility. Further, improved mycorhizal activity under CA favours higher P uptake by crop plants. Cation exchange capacity is substantially influenced by organic matter content in soils containing predominantly low activity clays. Improvement in the cation exchange capacity of soil improves the fertility status of soils under CA. Furthermore, decomposition of organic mulches adds organic acids to the soil resulting in low soil pH, which influences the bioavailability of many plant nutrients *viz*., Fe, Mn, Zn, Cu, etc.

## *CA as a viable solution to crop residue burning*

Residues and stubble retention on the soil surface have thus several benefits and must be retained for no-till system in the conservation agriculture mode rather than their burning, in order to moderate hydro-thermal regime, improve physical, chemical and biological attributes of soil health, inputs use efficiency, crop yields and yield sustainability besides minimizing inputs of fertilizer nutrients and GHG emissions.

## Implementation and comparative benefits

Until recently, non-availability of suitable machinery was a major constraint to direct drilling of wheat in combine harvested fields. This constraint has been resolved by the innovative latest version of the Turbo Happy Seeder, which is recognized as a significant technological innovation for *in-situ* residue management (Sidhu *et al.,* 2015). Through extensive trials, participatory validation and demonstrations, the Turbo Happy Seeder has proven to be extremely useful. It is a step forward for developing viable solution to rice residue burning.

It has been estimated that concurrent use of straw management system (SMS)-fitted combine and turbo happy seeder for wheat sowing with rice residue retention at soil surface resulted in 2-4 % higher grain yield of wheat compared to conventional tillage besides economizing the cost of production (NAAS, 2017). It has further been shown that this practice saves 30-40 kg $Nha^{-1}$ with significantly higher (10-15 %) nutrient use efficiency, eliminates pre-sowing irrigation, reduces evaporation, reduces risk of biotic and abiotic stresses, improves soil health by improving soil organic matter, improves environment by reduction in greenhouse gas emissions, reduces terminal heat effects (straw mulch reduces canopy temperature in wheat), reduces air pollution (as no particulate matter and obnoxious gases are released), improves health of on-farm and off-farm workers, and saves depletion of N, P, K and S in soil. Inclusion of this effort in carbon credit programme would help the farmers in receiving incentives and additional income. Farmers must be encouraged in adopting conservation agriculture by providing machinery at subsidised rates and through custom hiring system.

## Role of Government

The Government of India is presently giving 50 % subsidy on purchase of machinery and 80 % subsidy to those who are prepared to do custom hiring service. National guidelines have also been issued to prevent burning of crop residues, thereby ensuring their proper recycling for improving soil health. Thus, CA can serve as a win-win strategy for sustainable intensification of crop productivity, improvement of soil health and minimizing environmental pollution by avoiding crop residue burning.

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**ARTICLE - 3**

## Conservation agriculture-based maize-wheat cropping system improves aggregate–associated N, aggravates $N_2O$ emission but does not increase global warming potential

Conservation agriculture (CA) is a farming practice that emphasizes on sustainable use of resources and minimizes adverse impact on environment and climate. Studies have demonstrated that CA is helpful in increasing productivity, reducing water loss from soil system, and thus, is a useful practice for soil conservation in India (Bhattacharyya *et al*., 2015; Das *et al*., 2016).Conservation agriculture generally affects soil aggregation and aggregate-associated soil organic matter (Bhattacharyya *et al*., 2018). However, it generally aggravates $N_2O$ emission. Increased $N_2O$ emissions have been linked to increased denitrification under reduced tillage due to the formation of microaggregates within macroaggregates that create anaerobic micro sites (Hermle *et al*., 2008) with increased microbial activity leading to greater competition for oxygen. Despite CA promoted as a climate resilient technology, limited information is available on its impacts on N storage within soil aggregates *vis-a-vis* its global warming potential (GWP) under tropical agro-ecosystems. Hence, this study assessed the effects of a medium term (5 years) CA on total soil N (TSN) changes in bulk soils and aggregates, $N_2O$ emission and GWP under maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) system in the Indo-Gangetic Plains. The objectives were to study the effect of tillage and residue management practices on changes in aggregate size, aggregate-associated N, and its effect on TSN and eventually on GWP and greenhouse gas (GHG) intensity, following a long-term maize-wheat rotation field trial, under permanent bed planting with residue retention (CA).

### *Materials and Methods*

A field study was initiated on the Research Farm at the ICAR-Indian Agricultural Research Institute (IARI), New Delhi (28°37′- 28° 39′ N latitude and 77°9′-77° 11′ E longitude); 217 m above the mean sea level), India in 2010. Before 2010, the experimental field was under long term rice–wheat system. The soil (0–15 cm layer) was sandy clay loam with pH 7.7 (1:2.5 soil:water), EC 0.64 $dSm^{-1}$, oxidizable SOC 5.2 g $kg^{-1}$, total soil N 1863 kg $ha^{-1}$, 0.5M $NaHCO_3$ extractable P 23.3 kg $ha^{-1}$, and 1 N $NH_4OAc$ extractable K 250.5 kg $ha^{-1}$.The treatments were: conventional tillage (CT), zero tillage (ZT) with planting on permanent narrow beds (PNB), PNB with residue (PNB+R), ZT with planting on permanent broad beds (PBB), PBB with residue (PBB+R), ZT and ZT with residue (ZT+R). Soil samples were collected after five years of a maize–wheat system, and TSN in bulk soils and their aggregates (as measured using a wet sieve apparatus) of the 0-5 and 5-15 cm soil layers were measured along with $N_2O$ and $CO_2$ emissions during the fifth year (2014-15). Gas samples were obtained from experimental field from all the plots at 0, 30 and 60 minutes. The closed chamber technique (Bhatia *et al*., 2011) was used for collection of gas samples. Gas samples were obtained using a 50-ml syringe via a hypodermic needle at 0, 30 and 60 minutes for $N_2O$-N and $CO_2$-C. Nitrous oxide-N concentrations in the gas samples were analyzed using a gas chromatograph. Carbon dioxide-C in the gas samples was converted to $CH_4$ using a methanizer (Ni catalyst, 320°C). This was then analyzed using a flame ionization detector. The GWP on a 100-year time horizon was determined for all management practices using the following equation:

$$\text{GWP (kg } CO_2 \text{ eq. ha}^{-1}) = [N_2O \text{ (kg ha}^{-1}) \times 298] + [CO_2 \text{ (kg ha}^{-1}) \times 1] \quad \text{.......} (1)$$

where, 298 and 1 are GWP coefficients to convert $N_2O$ and $CO_2$, respectively, to $CO_2$ equivalents (IPCC, 2013).The cumulative fluxes for both the seasons were multiplied with their respective GWP to get the GWP during the cropping season of the maize-wheat system, and also during the fallow period between the maize and wheat crops.

***Results and Discussion***

The PBB+R plots had significantly higher proportion of large macro-aggregates (> 2 mm) compared with CT plots in both 0-5 and 5-15 cm soil layers (Table 1). The soils under PBB+R had 37 and 9% more macroaggregate- and microaggregate-associated N concentrations, respectively, in topsoil (0-5 cm layer) than those under CT (Table 2). However, topsoil aggregation and aggregate-associated N contents of PNB+R and ZT+R were similar to those in CT plots. Greater topsoil TSN content in CA compared with CT plots could be due to: (i) more disruption of soil aggregates with CT than ZT/CA plots and (ii) improved soil aggregation under ZT/CA plots. In the maize–wheat cropping system, $N_2O$ emission was~21% and ~17% higher in soils with PNB+R and PBB+R, respectively, than with CT. The $N_2O$ fluxes following each split application of mineral fertilization were significantly higher in soils under ZT than under CT. The $CO_2$ emission was significantly lower in the ZT plots than in CT in case of both crops. Furthermore, the $CO_2$ emission was significantly higher under all residue-retained plots in both crops. Highest $CO_2$ emissions were observed in PNB+R plots. The dehydrogenase and fluorescein diacetate activities and TSN, microbial biomass N, $NO_3$-N and $NH_4$-N concentrations were also highest in PBB+R plots in topsoil. Overall, in the maize–wheat system, the GWP and GHG intensities in the CT, PBB+R and ZT+R plots were similar (Table 3). Thus, PBB+R practice is a better management alternative for soil N improvement than CT. That practice also had~22% greater system productivity in the maize-wheat cropping system and similar GHG intensity to CT plots.

**Table 1. Effects of conservation agriculture on soil aggregation after five years of maize-wheat cropping in the north-western Indo-Gangetic Plains**

| Treatment | Soil aggregation in the 0-5 cm layer | | | | Soil aggregation in the 5-15 cm layer | | | |
|---|---|---|---|---|---|---|---|---|
| | Large Macroaggregates (g 100 $g^{-1}$ soil) | Small Macroaggregates (g 100 $g^{-1}$ soil | Microaggregates (g 100 $g^{-1}$ soil) | Silt + clay associated fraction (g 100 $g^{-1}$ soil) | Large Macroaggregates (g 100 $g^{-1}$ soil) | Small Macroaggregates (g 100 $g^{-1}$ soil | Microaggregates (g 100 $g^{-1}$ soil) | Silt + clay associated fraction (g 100 $g^{-1}$ soil) |
| CT | 3.7b | 31.0b | 48.1a | 17.2a | 2.62b | 40.8a | 41.4a | 15.2c |
| PNB | 5.2ab | 36.5ab | 41.3b | 17.0a | 3.59ab | 44.4a | 36.5b | 15.5c |
| PNB+R | 4.6ab | 35.9ab | 41.5bc | 18.0a | 3.66ab | 44.4a | 33.0bc | 19.0ab |
| PBB | 5.3ab | 36.7ab | 40.7bc | 17.3a | 3.79ab | 45.1a | 30.7c | 20.3a |
| PBB+R | 6.4a | 40.0a | 36.1c | 17.5a | 4.45a | 45.6a | 32.0bc | 18.0b |
| ZT | 4.2b | 38.7a | 40.7bc | 16.4a | 3.16ab | 43.1a | 35.7b | 18.0b |
| ZT+R | 4.9ab | 35.6ab | 42.0b | 17.5a | 3.27ab | 45.0a | 35.0b | 16.7bc |
| F-value | 4.49 | 4.52 | 9.64 | 0.20 | 4.54 | 0.46 | 8.78 | 9.17 |

Means followed by similar lowercase letters within a column are not significantly different at P <0.05 according to Tukey's HSD test; **Source:** Bhattacharyya *et al*. (2018)

**Table 2. Effects of conservation agriculture on total soil N content within different soil size fractions after five years of maize-wheat cropping in the north-western Indo-Gangetic Plains**

| Treatment | Aggregate-associated total soil N (kg N $ha^{-1}$) in the 0-5 cm layer | | | | Aggregate-associated total soil N (kg N $ha^{-1}$) in the 5-15 cm layer | | | |
|---|---|---|---|---|---|---|---|---|
| | Large macroaggregate-associated N | Small macroaggregate-associated N | Microaggregate-associated N | Silt + clay associated N | Large Macroaggregate-associated N | Small macroaggregate-associated N | Microaggregate-associated N | Silt + clay associated N |
| CT | 29.3b | 218.4c | 299.0ab | 109.4b | 28.6c | 479.6b | 503.4a | 178.4c |
| PNB | 42.9ab | 259.5bc | 265.8b | 119.9ab | 40.6bc | 534.1ab | 445.6b | 184.0bc |
| PNB+R | 37.9b | 264.5bc | 280.7b | 123.5ab | 44.8ab | 672.8a | 415.8b | 209.0b |
| PBB | 43.6ab | 302.3ab | 329.0a | 128.3a | 47.1ab | 523.0ab | 331.0c | 245.4a |
| PBB+R | 52.9a | 341.5a | 290.1b | 128.6a | 56.9a | 600.2ab | 410.8b | 223.7ab |
| ZT | 30.0b | 278.0b | 280.7b | 111.4b | 35.2bc | 627.6ab | 403.6b | 203.8b |
| ZT+R | 36.6b | 258.1bc | 292.0b | 119.3ab | 35.9bc | 646.9ab | 405.7b | 188.2bc |
| F-value | 7.70 | 10.20 | 5.18 | 4.12 | 9.93 | 4.05 | 7.48 | 8.72 |

Means followed by similar lowercase letters within a column are not significantly different at P <0.05 according to Tukey's HSD test; **Source:** Bhattacharyya *et al*. (2018)

**Table 3. Effects of conservation agriculture on cumulative seasonal nitrous oxide and carbon dioxide emissions during whole year (2014-15) of maize-wheat, global warming potential and greenhouse gas (GHG) intensity**

| Treatment | Maize $N_2O$-N (g/ha) | Wheat $N_2O$-N (g/ha) | Maize $CO_2$ (kg/ha) | Wheat $CO_2$ (kg/ha) | GWP of the maize-wheat system (kg $CO_2$ equivalent) | GHG intensity (kg $CO_2$ equivalent $kg^{-1}$ grain yield of maize and wheat) |
|---|---|---|---|---|---|---|
| CT | 846e | 705bc | 792bcd | 772ab | 2320b | 0.255a |
| ZT | 901cd | 751b | 731e | 719bcd | 2255b | 0.210bc |
| ZT+R | 961ab | 841a | 802abc | 800a | 2480a | 0.220ab |
| PNB | 869de | 696c | 761cde | 693cd | 2217c | 0.239ab |
| PNB+R | 992a | 883a | 837a | 751abc | 2502a | 0.232b |
| PBB | 847e | 706bc | 734e | 682d | 2172c | 0.202c |
| PBB+R | 935bc | 875a | 816ab | 747abc | 2444a | 0.219ab |

Means followed by similar letters within a column for management practices are not significantly different at P<0.05 according to Tukey's HSD test; **Source:** Bhattacharyya *et al*. (2018)

***Conclusions***

This study revealed that in all CA practices (ZT+R, PNB+R and PBB+R), $N_2O$ emission and GWP were higher than in CT. However, the GHG intensities (equivalent carbon emissions per kg of grain yield) in the PBB+R and ZT+R plots were similar to that in CT. Between ZT+R and PBB+R, the PBB+R practice had more TSN accumulation and better soil aggregation than ZT+R. Thus, retention of residues on soil surface of PBB (PBB+R) could be a feasible mitigation practice to reduce soil emissions per unit productivity, increased total N storage in surface soils, improved soil aggregation that could have higher N use efficiency, and thereby save fertilizer N.

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## ARTICLE - 4

## Soil health: A holistic relook into the concept and assessment

In our eagerness to enhance total production during post-green revolution era in India, we grossly overlooked the need for balanced use of N:P:Ks and the importance of regulatory functions of soils. Farmers have even resorted to crop residues burning to enable easy intensification of the cropping systems. As a management practice, residue burning may hasten decline in quality of soil organic matter (SOM), the major soil ingredient facilitating soil aggregation and structural stability (Almendros *et al*., 2000; Dormaar *et al*., 1979; Malhi and Kutcher, 2007). Decline in SOM on account of continued dependence on chemicals alone, most of it is in imbalanced use in the form of N:P:Ks, reduces the ability of soils to absorb and retain soil moisture (Debano *et al*., 1976; Mataix-Solera and Doerr, 2004)and sustain biotic activity that makes soils a life-giving entity. The extensive and elaborate matrix of soil microorganisms and other life forms are known to contribute to soil health. Soil microbes play a key role in bioremediation, contribute to agricultural productivity by modulating disease, increasing plant tolerance to abiotic stress, and nutrient cycling (Manter *et al*., 2017). Any adverse effect on the regulatory soil functions (e.g. regulation of nutrient and moisture supplies, drainage congestions, soil erosion, etc.) also significantly reduces productivity of soils.

### *National Soil Health Card (SHC) Scheme*

Integrated analysis of the long-term rice-wheat yield trials conducted at 23 locations across the Indo Gangetic plains indicated that wheat yields had not improved even after 7-23 years, while surprisingly rice yields had declined during the same periods (Tirol-Padre and Ladha, 2006). Yield gap analysis in cereal crops, which provides a measure of untapped production capacity, has been observed to be large and highlighted by others as well (Aggarwal and Kalra, 1994; Aggarwal *et al*., 2000; Pathak *et al*., 2003a; Sahrawat, 2009).

Commensurate with this observation, Niti Aayog (Chand, 2018), in the recent time, has indicated that real income of the farmers has come down by 1.36% a year over the last five years. Therefore, they opined that the government will need to pursue both, the price and the production management system routes, to lift the lots of the farmers. In pursuance, Government of India launched the National Soil Health Card Scheme (SHC) in 2015 to address the laudable concerns of soil health in the country.

The efficacy of the SHC should depend on a three-step process, namely (i) collection of representative soil samples from farmers' fields, (ii) reliable chemical analysis of the soil samples in a timely manner, and (iii) development of soil test-based recommendations, duly recognising any other soil constraint such as drainage congestion, soil depths, poor soil moisture retention, rolling landscapes, soil erosion, poor biotic activity or soil-borne diseases/ pests, etc. (Karlen *et al*., 1997; Moebius-Clune, 2016). Any dislocation or delay in the three-step process could easily render the SHC service ineffective. There appears no research back stopping of the scheme as to how to reduce the burden of sample collection, analytical, and other works associated with testing of large number of soil samples in a given location.

Soils are the keystone of healthy and vibrant ecosystems, providing physical, chemical, and biological substrates and functions necessary to support. In the on-going National Soil Health Card Scheme (SHC), report cards provide chemical analysis on status of macro- (N,P,K,S) and micro-nutrients (Fe, Zn, Cu, Mn and/B) besides values for electrical conductivity (EC), pH and soil organic carbon(SOC). Thus, fertiliser recommendations in the soil health cards are primarily based on soil's chemical attributes and are based on either the area-general fertiliser recommendations of the state governments or on the basis of targeted yield equations developed by the soil test crop response scheme(STCR) of the Indian Council of Agricultural Research (ICAR).

SHC scheme in its present form does not take us beyond fertiliser recommendations and does not capture or monitor soil functions which make soils a living system, providing a range of eco-services for mankind (e.g. filtration of water, aquifer recharge, preventing nitrate pollution of drinking water, water retention and supplies, and climate change, etc.). In fact, the integrated crop production system and the related agronomic management practices are highly heterogenous and diverse in nature and the soil health parameters should address all these soil edaphic areas on a holistic mode. SHC scheme does not consider the physical and biological attributes of soils, which also can influence use efficiency of the resource inputs and crop production both positively and negatively. Besides, SHC provides little information on the impact of specific nutrient management practices on soil health. Thus, the SHC scheme misses the vital connection to soil health vis-a-vis multiple ecosystem services provided by soils. Our sole dependence on chemical- nutrient based approach for maintaining soil fertility has only contributed to continued and accelerated soil degradation. As a consequence, natural resources are now showing multiple signs of fatigue and decline (Duxbury *et al*., 2000; Hobbs *et al*., 2008).

***Resource management domain concept for reducing analytical workload in the laboratories***

The way forward to us, after considering the past approaches followed at national level, is that the crop production function should primarily be a game to start with relating it with homogeneity in fertility mapping. It seems that we need to employ the idea of using all existing georeferenced spatially distributed point data of different chemical tests (e.g. organic carbon, N, P and K, etc.) and use them to develop homogenous fertility zones (resource management domains) in GIS framework. In a delineated homogenous fertility management zone having a specific fertility combination (e.g. low N+ low P +medium K), the status of each nutrient may vary only within narrow available limits. Average fertility values from each delineated homogenous fertility management zone is then fed to computer-aided crop modelling approaches [Quantitative Evaluation of Fertility on Tropical Soils model (QUEFTS) (Barman *et al*., 2013), Nutrient Expert, or other nutrient management approaches] to base real-time recommendations (Barman *et al*., 2013; Maiti *et al*., 2006; Parihar *et al*., 2017; Pathak *et al*., 2003b; Singh *et al*., 2011; Xu *et al*., 2017; Yang *et al*., 2017) for different cropping systems following different management practices. Computer-aided modelling approache uses the inherent nutrient supplying capacity of the soils (omission plot data and nutrient interactions) but may also consider the effects of tillage, residues and soil management options in regulating the supply of nutrients vis-a-vis the need for additional fertiliser. The resource management domain concept will also enable adoption and use of the customised fertiliser grades in the specific fertility domains. At present, SHC report does not consider effect of poor irrigation water quality, known to limit crop production and degrade soil health. The enabling concept of resource management domains will link the problem of poor-quality ground waters with soil fertility/SHCs, and also recommend corrective measures. The soil fertility management domains, when integrated with high resolution soil health assessments from sensor data fusion technology (Veum *et al*., 2017), can enable diagnosis of all the soil health related attributes (physical, chemical and biological) constraining crop production in specific parcels of the management domains.

Globally, soil health is being increasingly assessed using remote/soil sensor technologies. Visible near-infrared diffuse reflectance (VNIR) spectroscopy has been used successfully to estimate several biological indicators of soil health (Das *et al*., 2015; Sahoo *et al*., 2012; Veum *et al*., 2017). Similarly, near-infrared reflectance spectroscopy (NIRS) has been used as a tool for detailing soil quality assessment related with chemical and physical parameters (Cécillon *et al*., 2009; Chaudhary *et al*., 2012; Kinoshita *et al*., 2012). We believe that chemical soil test reports together with remote sensing techniques provide a basis for quick, dynamic fertiliser recommendations for assessment and management of the soil health. Such an approach will permit attaining a balance in agronomic productivity and assess the impact of soil management practices on soil functions- crop production and eco-services provided by soils, a subject of intense research, currently underway. The proposed approach can make the SHC - truly a health card. Achieving these objectives requires a strong research and connected development platform for addressing soil health related issues across different agro-ecoregions.

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'Examples of management practices for maximizing soil health would include maintaining vegetative cover on the land year-round to increase organic matter input and minimize soil erosion, more reliance on biological approaches as opposed to chemical approaches to maintain crop productivity (e.g., rotations with legumes and disease-suppressive cover crops), and avoiding physical (mechanical) interventions, which might compact, alter or destroy the biologically-created porous structural arrangement of soil components.'

- Anonymous

## Upcoming events of the Society:

The following programmes will be undertaken during the following part of 2018-19

i) Awareness programme for students/farmers in the Govt. College of Durgapur.

ii) An interaction meeting of industry personnel, farmers and researchers at Narendrapur in the month of January, 2019.

iii) Follow-up programmes in Gosaba in the month of February, 2019.

iv) The 6th Annual Convention cum AGM was decided to be held at BCKV, Kalyani sometime in the month of March, 2019.

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