Conservation agriculture in cereal systems of south Asia: Nutrient management perspectives

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Abstract: In past, green revolution has paid dividends through impressive agricultural growth, which helped to keep balance between demand and supply in the past four decades. But, the real challenges have surfaced in the recent years with ever-increasing food demand due to burgeoning populations, degradation of natural resources and changing climatic conditions. The current food crisis witnessed a dramatic increase in world food prices, causing political and economical instability and social unrest in both poor and developed nations. Further, cereal crops (rice, wheat and maize) grown in different sequences, contribute bulk of the food in south Asia wherein production growth both in terms of grain and residue has slowed. Annual yield growth rates in rice and wheat were two to three times higher during 1966-94 than during 1995-2005. The challenges are further exacerbated with the sharp rise in the cost of food and energy, depleting water resources, vulnerability of soil to degradation and desertification & loss of biodiversity. In the last five decades in India nutrient use has increased by 1573%, total food grain production by 145% with an increase in area of just 3.5% and average yield increase of 125%. Therefore, the input use efficiency is decreasing at a fast pace, posing a threat of food insecurity and rapidly engulfing poor and under-privileged population. Conservation agriculture based management practices has proved to produce more at less costs, reduce environmental pollution, promote conjunctive use of organics (avoids residue burning), improve soil health and promotes timely planting of crops to address issues of terminal heat stresses in the region. Thus, for addressing the issues of resource fatigue and bridging ‘management yield gaps’, Conservation agriculture based management solutions are cornerstone. However, shift from conventional plow based farming practices to crop management practices based on key elements of conservation agriculture (minimal soil disturbance, surface retention of crop residues & efficient crop rotations) have varied nutrient dynamics and hence, the nutrient management perspectives. In this paper, we have made efforts to synthesize the information available in relation to nutrient management perspectives in conservation agriculture.

Key words: Conservation agriculture, cropping systems, soil, organic, carbon, tillage

Introduction

Global food supply has kept pace with demand in the past four decades due to impressive economic growth and linking global markets. During the second half of the 21st century, achievements of agriculture in South Asia in general and India in particular are among major global success stories. But, the real challenges have surfaced in the recent years with ever-increasing food demand due to burgeoning populations, degradation of land and natural resources and changing climatic conditions. To compound the challenges further, global climate change is likely to impact crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems, making production much more variable than at present. Climate change is contributing to shift in growing seasons for major crops such as rice, production of which could fall by 40% and decrease the acreage of favorable wheat growing areas in the country. The current food crisis witnessed a dramatic increase in world food prices, causing political and economical instability and social unrest in both poor and developed nations. Therefore for food and livelihood security, agricultural think tanks and United Nations have prioritized four major areas i.e. natural resources, climate change, water and food.

Cereal crops (Rice, Wheat and Maize) grown in different sequences, contribute bulk of the food in South Asia. Cereal based systems greatly affect the livelihoods and health of the urban and rural poor. Impressive gains in yields of these systems were mainly due to introduction of superior germplasm, increased use of fertilizer inputs, expansion in irrigated areas and partly by interactions between inputs. However in recent years, cereal production growth both in terms of grain and residue has slowed. Annual yield growth rates in rice and wheat were two to three times higher during 1966-94 than during 1995-2005. In the 1970s and 1980s, the peak of the green revolution, agricultural research helped to reduce urban and rural poverty by making food more affordable. In the 1990s, however, yield growth stalled, setting the stage for the higher food prices now being observed. It is now generally agreed that easy gains from the original Green Revolution Technologies (GRTs) have for the most parts been realized. Therefore, new sources of productivity growth other than through increasing the crop acreage will have to be tapped for food production to keep pace with population growth. The slowdown in yield growth mainly affected wheat and rice, with annual growth rates falling below 1% in recent years and staying well below annual population growth for the past decade or more. Therefore, the South Asian agriculture is currently facing twin challenges of resource fatigue and decelerating productivity growth of cereal crops. Also, there exist large yield gaps more particularly ‘management yield gaps’ ranging from 14-47%, 18 to 70% and 36 to 77% in wheat, rice and maize, respectively. In recent years, the challenges are further exacerbated with the sharp rise in the cost of food and energy, depleting water resources, vulnerability of soil to degradation and desertification & loss of biodiversity.

India alone need to produce additional 64 million tons (MT) of food over the next decade to achieve targeted 294 MT by 2020. The important question is where will the future productivity gains come from? Will germplasm improvement research repeat the progress achieved in last 4 decades? To us it seems that future growth in productivity in intensively cultivated systems will come increasingly from adoption of improved natural resource management practices designed to increase the efficiency of inputs in irrigated semi-arid, humid and sub-humid
tropics and improving the productivity in rained agro-
ecosystems. Incidentally the latter, are also the areas where seed-
based technologies alone have not done so well in enhancing
productivity. In the last five decades in India nutrient use has
increased by 1573%, total food grain production by 145% with
an increase in area of 3.5% and average yield increase of 125%.
Therefore, the input use efficiency is decreasing at a fast pace,
posing a threat of food insecurity and rapidly engulfing poor
and under-privileged population leading to increased poverty;
will be exacerbated further by the projected threats to agriculture
due to consequences natural resource degradation and
projected climate change effects.

Conservation agriculture based resource conservation
technologies has proved to produce more at less costs, reduce
environmental pollution, promote conjunctive use of organics
(avoid residue burning), improve soil health and promotes
timely planting of winter crops to address issues of terminal
heat stresses in the region. Like any other tillage and crop
establishment technology, it may not be a panacea for all present
day ills, but has proven to bring out south American Agriculture
out of its stagnant state almost 20 years ago, skyrocketing the
cereals and oilseed production system. Thus, for addressing
the issues of resource fatigue and bridging ‘management yield
gaps’. Conservation Agriculture based management solutions
are cornerstone.

In this paper we discuss the constraints of cereal production
system of South Asia and their solutions through Conservation
Agriculture based technologies and nutrient management
perspectives in CA.

Cereal systems of south Asia

Rice, maize, and wheat are major cereals contributing to food
security and income in south Asia. These crops are grown either
as a monoculture or in rotations in tropical and sub-tropical
environments of South Asia. In the irrigated and favorable rained
lowland areas, rice-rice (R-R), rice-wheat (R-W), and rice-maize
(R-M) are the predominant cropping systems. Rice-rice is
common in tropical climate with distinct dry and wet seasons
such as in South India, and in sub-tropical areas with mild cool
winter climate such as in Bangladesh, Eastern India, and Eastern
Nepal. Rice-wheat system is extensive in the sub-tropical areas
of the Indo-Gangetic Plains of Bangladesh, India, Nepal, and
Pakistan while R-M system is prevalent in tropical, sub tropical
and warm temperate areas. Rice-maize system, however, is less
extensive as compared to R-W or R-R if total area under these
cereal systems is considered. There are mainly three cropping
seasons in S. Asia: summer or kharif or monsoon (or called
kharif-II or aman in Bangladesh) from June/July to Sept/Oct,
rafi or winter from Oct/Nov to Feb/Mar, and spring or pre-
kharif or pre-monsoon (or kharif-I in Bangladesh) from Mar/ Apr to May/June. Rice (called transplanted aman or T. aman
in Bangladesh) is the main crop in summer while a wide range of
crops, including rice (called Boror Bangladesh, eastern India
and eastern Nepal), wheat, maize, winter pulses (chickpea, lentil,
field peas), potatoes, and mustard are grown in rabi or winter
season. In the pre-kharif or spring season, short-duration crops
such as maize, pulses (mungbean, cowpea), and rice (called aus
in Bangladesh) are grown. All the three major double-crop
systems (R-R, R-W, R-M) often include an additional crop such
as potato, lentil, chickpea, mustard, etc. in rabi, and jute, maize,
rice, mungbean, cowpea, etc. during pre-kharif-I or spring
season (Table 1).

Table 1. Area (Mha) under major cropping systems in four south
Asian countries

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Bangladesh</th>
<th>India</th>
<th>Nepal</th>
<th>Pakistan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice-rice</td>
<td>4.50</td>
<td>4.70</td>
<td>0.30</td>
<td>-</td>
</tr>
<tr>
<td>Rice-rice-rice</td>
<td>0.30</td>
<td>0.04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rice-wheat</td>
<td>0.40</td>
<td>9.20</td>
<td>0.57</td>
<td>2.20</td>
</tr>
<tr>
<td>Rice-maize</td>
<td>0.35</td>
<td>0.53</td>
<td>0.43</td>
<td>NA</td>
</tr>
<tr>
<td>Maize-wheat</td>
<td>-</td>
<td>1.80</td>
<td>0.04</td>
<td>1.00</td>
</tr>
<tr>
<td>Rice-pulses</td>
<td>-</td>
<td>3.50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rice-vegetable</td>
<td>-</td>
<td>1.40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Millet-wheat</td>
<td>-</td>
<td>2.44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rice-potato</td>
<td>0.30</td>
<td>NA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cotton-wheat</td>
<td>-</td>
<td>1.39</td>
<td>-</td>
<td>3.10</td>
</tr>
</tbody>
</table>

(Source: modified and updated from YS Saharawat, unpublished data,
Mayee et al., 2008; Timsina et al., 2010)

Table 2. Total uptake of major nutrients by cereal crops (Kg/tonne of
produce)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total uptake (Kg/tonne of main produce)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Rice</td>
<td>20.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>25.0</td>
</tr>
<tr>
<td>Maize</td>
<td>29.9</td>
</tr>
</tbody>
</table>

(Source: Fertilizer Statistics 2007-2008, FAI New Delhi)

In India the total nutrient uptake by these three major cereal
crops is as given in table 2.

Conservation agriculture: Principles and practices

Conservation Agriculture (CA) is a concept for optimizing
crop yields, and economic and environmental benefits. The key
elements of CA include no-tillage, adequate retention of crop
residues on the soil surface for mulching, innovative cropping
systems and measure to reduce soil compaction through
controlled traffic. Freewheeling of the farm machinery in moist
fields creates ruts and compacts soil. This must be avoided if
zero-till is to be practised for a longer time. These CA principles
are not ‘site-specific’ but represent ‘unvarying objectives’ that
are practised to extend CA technologies efficiently across all
production conditions. Conservation Agriculture (CA) systems
are not only about precision planting using seed drill or planters
without tillage or significantly reduced tillage. But, is also about
management practices (weed, water, nutrient and IPM etc) that
make O-till technology successful and provide added advantage
to the farmers. The way crop management is practised in different
ecosystems (e.g. plains and sloppy lands) may vary the importance
of the “unvarying objectives” according to local situations,
resource endowments of the farmers and farming systems. This
only suggests that CA systems (zero-tillage) are ‘divisible’ in nature and ‘flexible’ in operation allowing farmers to benefit from them under diverse situations. Conservation agriculture based RCTs are an “open” approach, easier to mainstream. CA therefore, will be able to quickly address two critical needs that address concerns faced by South Asian agriculture today - farm economics and climate change.

**Conservation agriculture based crop management - A paradigm shift**

There has been a tremendous shift in the production variables of modern farming over traditional plowed based farming (Table 3). Even then, the most agronomic works revolved around tillage and labor intensive farming. Declining soil organic carbon (SOC) status of soils has been main shift in agriculture from ‘traditional animal based subsistence’ to ‘intensive chemical and tractor based’ agriculture that multiplied problems associated with sustainability of natural resources. The SOC concentration in most cultivated soils of India is less than 5 g/kg compared with 15 to 20 g/kg in uncultivated virgin soils. Low SOC concentration is attributed to plowing, removal of crop residue and other bio-solids, and mining of soil fertility (Lal, 2004). Large acreage of cultivated lands shows fertility fatigue and deficiency of micro-nutrients in many intensively cropped areas. This adds to our challenge of making farming more profitable.

Globally, it took few decades for the farming community to shift away from the common belief that summer-fallow / ploughing was the only way to improve farm productivity to a belief that drastically reduced or minimum/zero tillage was more advantageous. Conservation agriculture (CA) is being widely accepted as an important component of the overall strategy for enhancing productivity, improving environmental quality and preserving natural resources for food security and poverty alleviation in such areas. The basic components of CA include drastic reduction in tillage, adequate retention of crop residues on the soil surface, use of economically feasible diversified crop rotations, avoidance of freewheeling and practice of controlled traffic, if possible (Kassam and Friedrich, 2009). These elements of CA are not site-specific but represent unvarying objectives that are practiced to extend CA technologies efficiently across all production conditions. No-till agriculture is considered as a revolutionary step in the direction of preventing land degradation and rehabilitation of the resilient but fragile lands. No-till agriculture together with other associated management practices such as direct seeding into loose crop residues to provide soil cover and to conserve soil moisture, judicious choice of crop rotations and agro-forestry tree species constitutes conservation agriculture (CA). CA is an innovation process of developing appropriate CA implements, crop cultivars etc. for iterative guidance and fine-tuning to modify crop production technologies. CA practices, many reduced till variants, have been widely adopted in tropics/subtropical and temperate regions of the world to grow rainfed cereals systems, cereals between rows of perennial crops, irrigated rice-wheat systems, and development of agriculture in hillsides sloping lands. CA has steadily increased worldwide to cover about 7% of the world arable land area.

It must be remembered that the conservation tillage (CT) and conservation agriculture (CA) are not synonymous. CT refers to reduced/minimum tillage with some residues left on the surface. In CA tillage is avoided or drastically reduced and adopt efficient crop rotations. Zero-till drill simply disturb the soil in a narrow slit just to place seed in the soil and hence minimal till system is very close to no-till system practiced in conservation agriculture. Soil conservation (SC), conservation tillage (CT) and resource conservation technologies (RCTs) are also not synonymous to conservation agriculture (CA). All RCTs may not form part of the CA. The CA requires a paradigm shift in our thinking and actions as indicated below:

**Experiences with conservation agriculture based technologies in south Asia**

The growing realization that the agriculture of the post-Green Revolution era will be guided by the need to produce more quality food from the same land and water resources, besides sustaining environmental quality, only adds to the challenge. The zero-till wheat in rice-wheat cropping system has been addressing the several issues of sustainability and its success has encouraged the farmers to adopt the double no-till practice for long-term sustainability of the system. The major benefits (Gupta et al., 2007a, 2007b, Saharawat et al., 2010) of zero-till

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Production variables scenario</th>
<th>Traditional</th>
<th>New/Changing scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cropping systems</td>
<td>Less intensive</td>
<td>More intensive, Monotonous</td>
</tr>
<tr>
<td>2</td>
<td>Water table</td>
<td>High</td>
<td>Low, imbalances, multiple nutrient deficiencies surfaced</td>
</tr>
<tr>
<td>3</td>
<td>Soil fertility</td>
<td>Medium to high fertility</td>
<td>Laser assisted</td>
</tr>
<tr>
<td>4</td>
<td>Land leveling</td>
<td>Traditional</td>
<td>No -till/drastically reduced tillage</td>
</tr>
<tr>
<td>5</td>
<td>Tillage</td>
<td>Repeated intensive tillage</td>
<td>Crop based</td>
</tr>
<tr>
<td>6</td>
<td>Organic recycling</td>
<td>Animal based</td>
<td>Wider</td>
</tr>
<tr>
<td>7</td>
<td>Cultivar choices</td>
<td>Limited</td>
<td>More extremes</td>
</tr>
<tr>
<td>8</td>
<td>Climatic variability</td>
<td>Less</td>
<td></td>
</tr>
</tbody>
</table>

- Uneven field levels
- Excessive tillage
- Residue burning or incorporation
- Use of ex-situ FYM/ composts
- Green manuring (incorporated)
- Free-wheeling of farm machinery
- Single or sole crops
- Monotonous cropping system
- Crop based management

Precision land leveling: No till / drastically reduced tillage
Surface retention of residues: In-situ use of organics/composting
Brown manuring (surface drying): Controlled traffic
Inter cropping / relay cropping: Diversified cropping system
Cropping system based Management.
technology include (i) reduced costs due to savings in fuel and labor, (ii) timely planting of kharif and winter season (rabi) crops, resulting in higher yields, (iii) reduced weed density (iv) saving of irrigation water (up to 15-20%), (vi) improved input use efficiency because of better crop stands due to good seed and fertilizer nutrients placement, and (vii) build-up in soil organic carbon due to reduced burning of crop residues (Phillips et al., 1980) & reduced oxidation of soil C. Presently we are at half way of conservation agriculture (CA) and evaluation and accelerating the adoption of double no-till is the immediate step towards CA. Several studies conducted across the production systems under varied ecologies of South Asia revealed potential benefits of CA based RCTs on resource conservation, use efficiency of external inputs, yield enhancement and adaptation to terminal heat effects (Gupta et al., 2003; Malik et al., 2005; Gupta & Seth, 2007, Gupta & Sayre, 2007, Gupta et al., 2010, Jat et al., 2010). Laser assisted land levelling being practiced over 1.5 m ha in south Asia saves on water by 25-30 %, improve yields by 5-15 % with other associated benefits (Jat et al., 2009a, 2009b). Zero tillage in cereal systems have helped in saving in fuel, water, reduce cost of production, improve system productivity and soil health (Gupta et al., 2003; Malik et al., 2005; Gupta & Seth, 2007, Gupta & Sayre, 2007, Jat et al., 2009a; Saharawat et al., 2009, 2010). The results across IGP suggests that double no-till with retention of crop residues produced higher system productivity over conventional and zero till without residues (Fig 1). Raised bed planting technology provides opportunity for diversification through intensification and saves on water (Jat et al., 2005, 2006). Residue management in zero till systems (surface retention) helps in improving soil health (Sharma et al., 2008) reducing GHG emission equivalent nearly 13 tonnes/ha reduced oxidation of soil C. Presently we are at halfway stage and also regulating canopy temperature at grain filling stage to mitigate the terminal heat effects in wheat (Jat et al., 2009c, Gupta et al., 2010).

Adoption of CA based practices in south Asia

CA practices have been widely adopted in tropics/subtropical and temperate regions of the world for rain-fed and irrigated systems. Acreage of Conservation Agriculture is increasing steadily worldwide to cover about 108 m ha (Derpsch and Friedrich, 2009) globally (7% of the world arable land area). Thus, CA is an innovation process of developing appropriate CA implements, crop cultivars, etc. for iterative guidance and fine-tuning to modify crop production technologies. Recent estimates revealed that CA based RCTs are being practiced over nearly 3.9 m ha of South Asia (Anon., 2010).

Current nutrient availability and management scenario

On a macro-scale, N:P: K ratio of 4 : 2 : 1 has come to known as an ideal ratio, and a deviation in NPK consumption pattern, would suggest imbalanced fertilizers use- greater the departure, more the imbalance. In India, the average fertilizer consumption (Kg/ha) in paddy is 81.7 N, 24.3 P, 13.1 K; whereas in wheat is 99.6 N, 30.2 P, 6.9 K and in maize is 41.7 N, 14.7 P, 3.8 K. This is not entirely true as there is hardly any basis for the suggested single valued ideal N:P: K ratio. The ratio will be further widening with mismatch in the demand and supply of major nutrients across Asia (Figure 2).

The NPK ratio is likely to vary with crops, cropping systems, CA practices, soils and their reactions. It appears that there is need to work out new N:P: K ratios for basing fertilizer allocations for different regions. In the demand and supply of fertilizer nutrients, use of organics in agriculture seems inevitable particularly for correcting the N: K imbalances. From plant nutrition point of view, the importance of the concept of balanced fertilizer use lies in adjusting the level of fertilizer use, taking into account available soil nutrients, crops requirement for targeted production levels under specific soil-water-crop management practices (Gupta and Jat, 2010). New information seem to strengthen our understanding that conservation agriculture has a distinct influence on soil quality and nutrient dynamics as compared with the traditional agriculture based on intensive tilled systems. The current nutrient prescriptions are (i) age old, (ii) area general- not site specific (iii) designed for the

![Figure 1. Yield performance of RWCS under CA and conventional tillage practices in western and eastern IGP (Adopted from CIMMYT farmers participatory field trial data)](image)

![Figure 2. Nutrient balance in Asian agriculture (Source: FAO, 2008. www.fao.org)](image)
Conservation agriculture in cereal systems of.......contrast the production environment. The key elements of CA have direct and indirect bearing on the nutrient supplying/availability of soil which are described as below (Kassam and Friedrich, 2009).

1. **Minimum disturbance of optimum porous soil architecture**
   - Optimum proportions of respiration gases in the rooting-zone
   - Moderates organic-matter oxidation;
   - Porosity to water movement, retention and release at all scales
   - Limits re-exposure of weed seeds and their germination

2. **A permanent covering of sufficient organic matter over the soil surface**
   - Buffering against severe impact of solar radiation and rainfall;
   - A substrate for soil organisms’ activity;
   - Raised cation-exchange capacity for nutrient capture, retention and slow-release;
   - Smothering of weeds

3. **Cropping sequences and rotations which include legumes**
   - Minimal rates of build-up of populations of pest species, through life-cycle disruption;
   - Biological N-fixation in appropriate conditions, limiting external costs;
   - Prolonged slow-release of such N from complex organic molecules derived from soil organisms;
   - Range of species, for direct harvest and/or fodder;
   - Soil improvement by organic-matter addition at all depths reached.

**Table 4. Dynamism of production variables in changing scenario**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Production Variables</th>
<th>Dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cropping Systems</td>
<td>More intensive, Monotony</td>
</tr>
<tr>
<td>2</td>
<td>Water Table</td>
<td>Declined/increased</td>
</tr>
<tr>
<td>3</td>
<td>Soil nutrients</td>
<td>Deficiencies surfaced</td>
</tr>
<tr>
<td>4</td>
<td>Tillage, Land leveling</td>
<td>Contrasting</td>
</tr>
<tr>
<td>5</td>
<td>Organics</td>
<td>Different</td>
</tr>
<tr>
<td>6</td>
<td>Cultivar Choices</td>
<td>Wider</td>
</tr>
<tr>
<td>7</td>
<td>Climatic variability</td>
<td>Extremes</td>
</tr>
<tr>
<td>8</td>
<td>Policy</td>
<td>Changing</td>
</tr>
</tbody>
</table>

It is only prudent that new fertiliser recommendations should be able to mimic significant effects of residue retention vis-a-vis incorporation of organics having differential soil moisture and thermal regimes. Therefore, the paradigm shift from tilled to no-till CA systems require a serious thrust on nutrient management research to improve soil and crop productivity and environmental quality.

**Conclusion**

The key elements of CA including no-tillage, adequate retention of crop residues on the soil surface for mulching, innovative cropping systems are not ‘site-specific’ but represent ‘unvarying objectives’. CA systems are ‘divisible’ in nature and ‘flexible’ in operation allowing farmers to benefit from them under diverse situations and also cope with climate change. Globally CA has been widely accepted as an important component of the overall strategy for enhancing productivity, improving environmental quality and preserving natural resources for food security and poverty alleviation in such areas. CA requires a paradigm shift in our thinking and actions. The zero-till wheat in rice-wheat cropping system has been addressing the several issues of sustainability also reduce costs in fuel and labor, help in timely, produce higher yields, reduce weed density, help in saving of irrigation water, improve input use efficiency because of better crop stands due to good seed and fertilizer nutrients placement, and also build-up in soil organic carbon due to reduced burning of crop residues. Double no-till with retention of crop residues also produce higher system productivity, improve soil health, reduce GHG emission equivalent nearly 13 tonnes/ha and also regulates canopy temperature at grain filling stage to mitigate the terminal heat effects in wheat. The NPK ratio is likely to vary with crops, cropping systems and there is a need to work out new N:P: K ratios for basing fertilizer allocations for different regions especially in the CA based systems as CA has a distinct influence on soil quality and nutrient dynamics as compared with the traditional agriculture based on intensive tilled systems. Therefore, the focus should be “feed the soil and let the soil feed the plant”. It is also prudent that new fertiliser recommendations should be able to mimic significant effects of residue retention vis-a-vis incorporation of organics having differential soil moisture and thermal regimes. Therefore, the paradigm shift from tilled to no-till CA systems require a serious thrust on nutrient management research to improve soil and crop productivity and environmental quality.

**References**


