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Precision Nutrient Management Practices under Conservation Agriculture Based Maize–Wheat Cropping System

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INTRODUCTION

Among different maize-based cropping systems in India, maize-wheat ranks 1st and it is the 3rd most important cropping system after rice-wheat and rice-rice having an area of 1.8 mha that contributes about 3% in the food grain production of India. Maize is amongst the world's most widely produced and consumed cereal crops. It is called the 'Queen of Cereal' as it has the highest genetic yield potential among cereals. Given its photo-thermal insensitivity and its genetic amenability to reconstruction, it can be grown in diverse agro-climatic conditions. Consequently, it serves as a key raw material across various sectors – including livestock feed, starch, food processing and bio-ethanol. Additionally, derivatives of corn starch are actively used in diverse industries including pharmaceuticals, cosmetics, food processing, textiles and paper among others.

In India, the maize cultivated area is about 9.57 mha with productivity of 3.01 t ha-1 and total production of 28.77 million tons. India's maize productivity is lower than the global average of 5.82 t ha^{-1}. In terms of regional distribution, top 5 states which contributes 55% of India's total maize production are Madhya Pradesh (15%), Karnataka (14%), Tamil Nadu (10%), Bihar (9%) and Telangana (8%). In India, *kharif/rainy* is the main season for maize cultivation, contributing to more than 80% of the acreage and about 70% of production. The bulk of the maize production in India, approximately 47%, is used as poultry feed. Of the rest, 14% is used in the starch industry, 13% is used as livestock feed, 13% for food purposes, 7% as processed food and 6% for export and other purpose. Maize is a source of raw material for industry, where it is being extensively used for the preparation of corn starch, corn oil, dextrose, corn syrup, corn flakes, cosmetics, wax, alcohol and tanning materia. Maize consumed as second-cycle produce converted into meat, eggs and dairy products in high-income economies.

In developing countries, it is consumed directly and serves as a staple diet for around 200 million people.

Wheat is a major cereal crop, which plays a vital role in food and nutritional security. About 40% percent of the total food grain reserves of India is contributed by wheat crop. Normally wheat grain contains 60-68% carbohydrates, 8-15% protein, 1.5-2.0% fat, 2-2.5% cellulose and 1.5-2.0% minerals. Wheat grains contain a high number of vitamins, *i.e*., niacine and thiamine. Wheat is a staple food that is eaten in the forms of chapattis, upmas and puris. Various other items like biscuits, cakes, flakes, leavened bread and traditional Indian dishes like dalia and halwa are made from wheat. Wheat straw is a good source of feed for the cattles in our country. Wheat is energy- and protein-rich crop and has a high nutrient requirement. India stands the second in production and consumption next to China. Globally, during 2019-20, 216 mha area was covered under wheat cultivation with a production of 766 million tons. In India, wheat is grown on 31.36 mha with a production of 107.86 million tons with average productivity of 3440 kg ha^{-1}. The productivity of wheat varied across agro-ecologies and it ranged from as high as 5190 kg ha^{-1} in Punjab to 1250 kg ha^{-1} in Karnataka. Still, rice-wheat (RW) is the dominant cropping system in India. However, concerns of multiple challenges of sustainability in RW rotation vis-à-vis natural resource degradation in north-west Indo–Gangetic Plains (IGP) are well documented especially rapidly falling water table and deteriorating soil health. Diversification of rice with maize in the RW cropping system could help in enhancing crop productivity water-use efficiency, save irrigation water and labor costs and may restore/improve the soil health. With the development of high-yielding hybrids in maize which are competitive to rice concerning farm profitability and the resource-use efficiency under diverse soils and climatic conditions, the maize-wheat cropping system is gaining importance.

The IGP of India, covering about 44 mha, is dominated by irrigated cereal-based cropping sequences, of which maize–wheat (MW) rotation is the third most important (1.86 mha) cropping system after RW and cotton–wheat. However, conventional crop management practices entail high production costs, declined crop productivity and are inefficient in in put use. Moreover, excessive tillage often results in serious soil problems, *i.e*., surface crusting, deformation of soil aggregates, loss of soil organic matter and sub-soil compaction. These are major challenges facing the agricultural sustainability the country looking for such challenges can be solved/mitigated by adopting recent technologies focused on efficient resource use and their conservation. Under such a situation, conservation agriculture-based crop management practices should have to receive high priority to ensure the fast gains of agriculture productivity with low cost. Conservation agriculture (CA) involving various resource conservation technologies (RCTs) encompasses practices that enhance resource or input-use efficiency and provide immediate, identifiable and demonstrable economic benefits such as reduction in production costs, saving in water, fuel and labor requirements and timely establishment of crops resulting in improved yields. CA is based on three principles, i.e., (i) minimum tillage and soil disturbance, (ii) permanent soil cover with crop residues and live mulches and (iii) crop rotation and intercropping. In general, the adoption of CA bring many benefits for the soil health parameters, including increasing soil organic matter, decreasing runoff and soil erosion, increased water infiltration and reduced evaporation and increasing soil water storage. Due to these benefits, the area under CA has expanded from 45 mha to 180 mha in the period from 1999 to 2015. However, in India, the area under CA is limited to only 1.5 mha. Adoption of CA in South Asia has skewed distribution, mainly in Indo-Gangetic Plains (IGP) in India, Pakistan, Nepal and

Bangladesh. Cereals, uptake only 40–60% of soil nitrogen. Farmers compensate for the low N uptake by increasing N application, to maintain economic grain yield. Therefore, N losses amounted to more than 50% of applied N, leading to adverse environmental and socio-economic impacts including contaminating surface and groundwater and N gaseous emissions. Therefore, it is urgent to identify economically and environmentally-friendly N management options that increase N availability at critical growth stages to increase yields and N use efficiency. Healthy soil is capable of producing higher crop yields under favorable as well as extreme climatic conditions. Reduction in soil disturbance (tillage) and provision of optimum crop nutrition can enhance dry matter accumulation and improve plant's metabolic activities, resulting in better yield, leaf area index (LAI) and crop architecture due to plant x environment interactions. The use of fertilizer nutrients in sub-optimal, optimal and super-optimal doses potentially affects the crop yield and resource use-efficiency. Enhanced crop yield, water and resource use efficiency under balanced application of fertilizer nutrients have been observed in maize and wheat-based systems.

Published findings from several studies have shown that permanent bed (PB) planting is suitable for enhancing crop productivity and reducing the production cost as well as conserving natural resources. It also allowed the maintenance of uniform permanent soil cover for higher moisture/water capture and conservation. Direct planting of crops in zero tillage (ZT) and permanent bed (PB) plots, with balanced fertilization, led to favorable alterations in soil water aggregates, total porosity maintaining soil and its moisture content and as a consequence, it improved plant water availability. CA-based (ZT and PB) practices also improve soil infiltration (Nielsen et al., 2009), water retention and hydraulic conductivity. CA-based ZT system could provide additional nutrients, improve soil physical properties, better water-use efficiency and improve nutrient use efficiency. Enhanced crop yield, water and resource use efficiency under balanced application of fertilizer nutrients have been observed in maize and wheat-based systems. Bed planting of maize helps in proper plant establishment, increases input efficiency, yields and opens up avenues for a double no-till system. CA practices have a significant effect on nutrient transformation and distribution in soils and the effects are related to SOC content and its pools. The distribution of nutrients in soil under CA differs from that in conventional tilled (CT) soil as CA practices enhance the stratification of nutrients and their availability near the soil surface. In CA-based practices, the crop roots density is usually more near the soil surface compared to CT and more nutrients are taken up from near the soil surface. The zero tillage and crop residue as mulch in CA will have implications on soil moisture regime and nutrient dynamics that in turn will influence nutrient response, nutrient availability and use efficiency. Precision agriculture practices being a new area of research especially in maize–wheat crop rotation under CA where little or not much work has been done. The outcome of this study would not only add to the existing scientific knowledge on the subject but also be of immense practical significance to the farmers and other stakeholders by way of suggesting viable technologies for soil health improvement/maintenance and enhancing nutrient use efficiencies. These understandings, therefore, lead to support the setting of new benchmarks to evaluate existing agricultural systems and to improve future agricultural systems to balance the future need through enhanced yields and resource use efficiency and soil health.