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Rice Residue Management for Improving Soil Quality

Mohammad Shahid*, Rahul Tripathi, Sangita Mohanty, Kasturi Thilagam and A. K. Nayak

Central Rice Research Institute, Cuttack - 753006, Orissa

**Corresponding Author: Email - shahid.vns@gmail.com*

Introduction

Crop residues are good sources of plant nutrients and are important components for the stability of agricultural ecosystems. About 400 million tons of crop residues are produced in India alone. In areas where mechanical harvesting is practiced, a large quantity of crop residues are left in the field, which can be recycled for nutrient supply. About 25% of nitrogen (N) and phosphorus (P), 50% of sulfur (S), and 75% of potassium (K) uptake by cereal crops are retained in crop residues, making them valuable nutrient sources. Both rice and wheat are exhaustive feeders, and the double cropping system is heavily depleting the soil of its nutrient content. A rice-wheat sequence that yields 7 tons per ha of rice and 4 tons per ha of wheat removes more than 300 kg N, 30 kg P, and 300 kg K per ha from the soil. If crop residues could be better managed, this would directly improve crop yields by increasing soil nutrient availability, decreasing erosion, improving soil structure and increasing soil water holding capacity as a consequence of improving soil organic matter content (Yadvinder Singh *et al.*, 2005). Although during the last three decades fertilization practices have played a dominant role in crop production system, crop residues, the harvest remnants of previous crop, still play an essential role in nutrient cycling. Incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in soil and subsequent nutrient transformations. Through this chain of events management of crop residues regulates the efficiency with which fertilizers, water and other reserves are used in a cropping system.

Farming activities in many parts of the world have resulted in large declines in soil organic matter (SOM) and concomitant degradation of soil physical and chemical properties, resulting in reduced crop yields and quality (Dalal and Mayer, 1986). To a large extent, this has occurred through the inappropriate management of crop residues, fertilizers and tillage. World population growth, demands for food security, limited land resources and global climate change signal the need for farming systems that are sustainable and reverse the decline in SOM to levels adequate for stable soil structure and better water and nutrient retention. The use of crop residues, the manipulation of their quality and inorganic inputs play a key role in sequestering carbon and building up soil fertility.

Rice residue management options

There exist several options for managing crop residues. These include being removed from the field, left on the soil surface, incorporated into the soil, burned *in situ*, composted or used as mulch for succeeding crops. Throughout the tropics there is little recycling of crop residues in the field – these are either harvested for fuel, animal feed or bedding or are burned in the field. Crop residues removed from the field can also be used as bedding for animals, a substrate for composting, biogas generation or mushroom culture or as a raw material for industry. Local conditions determine the disposal method. Currently, in China, North Vietnam, India, Bangladesh and Nepal, complete removal of straw from the field is widespread in areas with hand harvest and great demand for straw as fodder, as fuel or for industrial purposes, causing large nutrient export from rice fields. Open field burning of rice straw is predominant in areas with combine harvesting (northern India, Thailand, parts of China) or where manual threshing is done in the field (Indonesia, Malaysia, Myanmar, Philippines, southern Vietnam). In many parts of the tropics, crop residues are burned in the field due to the ignorance of farmers about their value and lack of proper technology for in situ incorporation of residues. For example, in the intensive rice-wheat cropping system in the Indo-Gangetic plains of South Asia, crop residues, particularly rice straw are not used as animal feed and are disposed of by burning. This is a cost effective method of straw disposal and helps to reduce pest and disease populations resident in the straw biomass, but it also causes pollution by releasing CO_2, N_2O, NH_3 and particulate leading to global warming and health concerns (Kirkby, 1999). It also reduces the number and activity of soil microbes. The magnitude of C and nutrient loss during burning is influenced by the quantity of residue burned and the intensity of the fire. Complete burning of rice straw at 470 °C in muffle furnace resulted in 100, 20, 20 and 80% losses of N, P, K and S, respectively (Sharma and Mishra, 2001).

Decomposition of rice residues

Decaying of crop residues starts as soon as the residues come into contact with the soil. The process of decomposition is controlled by the interaction of three components: the soil organisms or biological processes, the quality of crop residues, and the physical and chemical environment. The combination of these components determines not only the rate of decomposition of crop residues but also the end product of the decomposition process. Burying of rice straw in soil has been reported to accelerate the decomposition in comparison with placing the straw on the soil surface (Kumar and Goh, 2000). Residues rich in lignin and polyphenol contents experience the lowest decay. Decomposition of crop residues occurs at a rapid rate under the warm and humid conditions of the tropics. Factors that control C decomposition also affect the N mineralization from crop residues. Decomposition of poor-quality residues with low N contents, high C:N ratios and high lignin and polyphenol contents generally results in microbial immobilization of soil and fertilizer N. A large number of organic compounds, particularly phenolic acid and acetic acid are released during the decomposition of crop residues under anaerobic conditions. The accumulation of these organic compounds can adversely affect the seedling growth.

Residue management effects on soil properties

In recent years, the concept of soil quality has been suggested as a tool for assessing the long-term sustainability of agricultural practices at local, regional, national and international levels. Crop residue management is known to affect either directly or indirectly most of the soil quality indicators-chemical, physical and biological. It is perceived that soil quality is improved by the adoption of sound crop residue management practices (Karlen *et al.*, 1994). Long-term application of crop residues increased the organic matter, total N content and availability of several nutrients (though to a small extent) in soils. The rate of increase in soil organic matter is low due to high turnover rates of C under tropical conditions. Mineralization and immobilization of N occur simultaneously in the soil. The residue quality and availability of soil N are important determinants of N mineralization-immobilization occurring during residue decomposition. Mineralization of organic N depends on the N requirements of the soil microbial population, the biochemical composition of the decomposing crop residue and several soil and environmental factors. Crop residue management can affect N immobilization and stabilization processes important to efficient utilization of N from fertilizers, crop residues and soil organic matter availability of nutrients from crop residues depends to a great extent on mineralization of nutrients from the crop residues in relation to crop demand. The application of crop residues can cause short-term immobilization of both P and S, particularly in aerobic soils. Only a small fraction (5%) of the residue P is available to the plants in the first year, and a major fraction is immobilized as microbial biomass (Stevenson, 1986). Crop residues contain large amounts of K, which upon incorporation increased K availability in soil and helped to reduce K depletion from non-exchangeable K fraction of soil (Chatterjee and Mondal, 1996). Residue management practices affect soil physical properties such as soil moisture content, temperature, aggregate formation, bulk density, soil porosity and hydraulic conductivity. Increasing amounts of rice residues on the soil surface reduce evaporation rates and increased duration of first-stage drying. Thus, residue-covered soils tend to have greater soil moisture content than bare soil except after extended drought. The effect of residues on soil physical properties is dependent on soil type, tillage, soil moisture conditions, duration of study, and cropping system followed. Microbial bioniass, a small (1-5% by weight) but active fraction of soil organic matter, is of particular concern in soil fertility considerations because it is more susceptible to management practices than the bulk organic matter (Janzen, 1987). Although SMB values are only a small portion of total C and N in soils, this living portion of soil contains a substantial amount of nutrients needed for crop growth. The amount of microbial biomass and microbial activity depends on the supply of organic substrates in soil. Therefore, regular addition of a sufficient amount of organic materials such as crop residue is important in the maintenance of microbial biomass and improvement of soil fertility.

In South Asia, rice crop occupies a major share of total arable land. The recycling of its residues has the great potential to return a considerable amount of plant nutrients to the soil in the rice based crop production systems. Particularly the rice-wheat cropping system is the most intensive production system in the country. The yield stagnation consequent upon the declining soil organic carbon is a major threat to this system. Therefore it is a great challenge to the agriculturists to manage rice residues effectively and efficiently for enhancing sequestration of carbon and maintaining the sustainability of production. The application of current knowledge on residue management will help reduce the adverse effects of crop residues on crop yields. Hence, it may be concluded that nutrient cycling through crop residues holds great promise in securing a high level of crop productivity as a result of improved soil quality.

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