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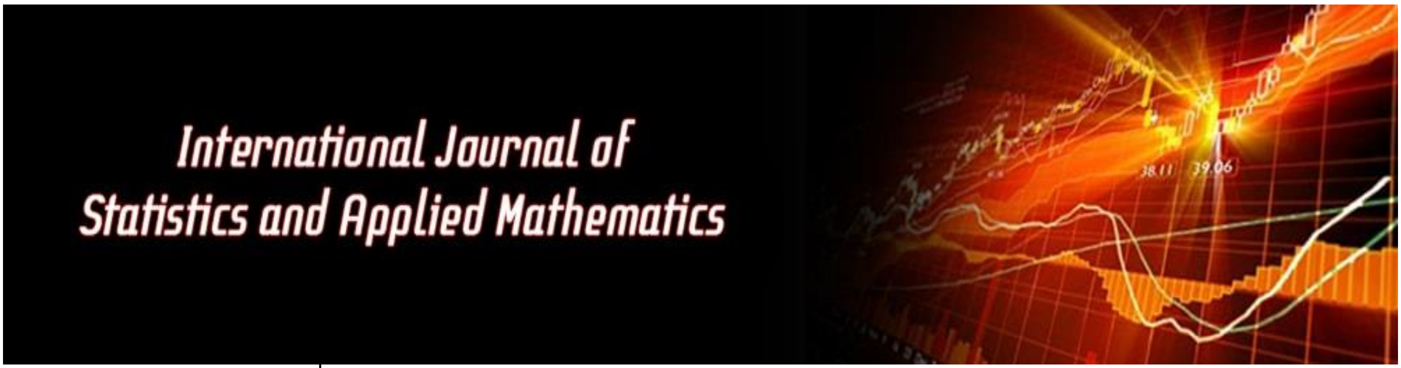

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A review on crop residue incorporation in soil under the Rice-Maize cropping system

Dr. Mukesh Kumar Pandey and Ankita Singh

Abstract
Present paper was a review crop residue incorporation in soil as an important practice in natural resources management as it helps maintain soil productivity and fertility. Crop residues, such as stalks, leaves, and stems, are rich in organic matter and nutrients that can benefit the soil and subsequent crops. When crop residues are incorporated into the soil, they contribute to the formation of organic matter, which improves soil structure and stability. Organic matter helps create pore spaces in the soil, allowing for better water infiltration and drainage. This is especially important in areas with heavy rainfall or compacted soils. In addition to improving soil structure, crop residue incorporation also enhances nutrient cycling in the soil. As the residues decompose, nutrients are released and become available for plant uptake. This reduces the need for synthetic fertilizers and promotes sustainable agricultural practices. Furthermore, crop residue incorporation can help control soil erosion. The residues act as a protective layer on the soil surface, reducing the impact of raindrops and preventing soil particles from being washed away. This is particularly crucial in areas with sloping terrain or high wind speeds.
To effectively incorporate crop residues into the soil, proper management practices should be followed. This includes shredding or chopping the residues to facilitate decomposition, adjusting the timing of incorporation to coincide with favorable soil conditions, and ensuring proper nutrient management to optimize nutrient release. Overall, incorporating crop residues into the soil is a valuable practice in natural resources management. It not only helps maintain soil productivity and fertility but also contributes to sustainable agriculture and environmental conservation. By implementing this practice, natural resources management professionals can continue their efforts in preserving and protecting our precious natural resources for future generations.

Keywords: Rate of metabolism, blood mass stream rate, warm conductivity, warm era, limited component method, Pennes Bio - Heat Model

Introduction

Rice (*Oryza sativa* L.) and maize (*Zea maize L*) are grown in 3.5 million hectares in Asia, in which 1.5 m ha is included in South Asia. These crops are grown in double or triple crop systems on the same land in the same year to meet the rice demand for the fast growing human population and maize demand of poultry and livestock (Timisina *et al*., 2010) [34]. The rice - maize systems are growing fast in south Asia and Andhra, Telangana and nearby states in India because of higher yields and profit potential compared to rice. The system water requirement is less than the demand for rice -rice. The practical utility/scalability of rice–maize area can be expanded up to 0.53 m ha in India and net profitability can be increased to 530 crore (Rs.10000 ha^{-1}). The some patches of rice-rice (4.7 m ha), rice-rice-rice (0.04 m ha), rice-wheat (9.2 m ha) and rice-pulses (3.5 m ha) area can be diversified to rice–maize system (Tuti, 2018). In recent year, shortage of water has become an important issue however, to avoid water shortage and increasing irrigation efficiency crops, which needs light irrigation like maize should be included in the system (Kumara *et al*., 2015) [88].

In Chhattisgarh, diversification needs to be adopted with fast-growing rate to increase the income of farming community. However, farmers are nowadays adopting economically viable cropping system having high yield potential and economic return such as rice- maize without caring soil health. The research data of many environments in India highlighted gap between of potential yield of maize and actual yields achieving by the farmers (Bajpai *et al*., 2002) [11].

The nutrient demand for rice - maize system is high due to high-yielding varieties of rice and the removal of the high nutrients from maize hybrids. The nutrient demand is related to the high productivity of both the crops in the system (Khare *et al.*, 2014) [35]. However, the soil fertility of rice - maize cropping system declining very fast, especially where residues of both crops are usually removed from fields. A large effort is required to maintain the fertility of soil in rice – maize system (Mussnug *et al.*, 2006 and Ali *et al.*, 2012) [36, 3].

Rice - maize system has a negative impact on land and production systems, causing suspicions in the long-term stability of the system as reported by Sistani *et al*. (1998) [37]. The crop residue incorporation can have negative effects on next crop, although some studies have negative effects of incorporating residues in rice-wheat cropping systems decreased after some initial years. The negative effects can results from the immobilization of soil and fertilizer N during early stages of decomposition resulting in N deficiency in the succeeding crops (Beri *et al*. 1995 and Mary *et al*. 1996) [23, 38].

Timicina *et al.* (2010) [34] advocated that traditional cultivation in rice - maize system reduces the fertility status of soil, which adversely affected the productivity and quality of rice. In intensive rice-based cropping system, nitrogen mainly goes for leaching losses (Howard, 1993 and Mai *et al*., 2010) [39, 40].

Mahto *et al*. (2018) [41] found that in rice-maize cropping system application of 100 kg ha^{-1} N, 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O along with 25 kg ha^{-1} ZnSO4 in rice registered the highest grain yield (47.5q ha^{-1}) and as well as in the same plot in succeeding maize crop, application of 120 kg ha^{-1} N, 75 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O produced significantly higher grain (86.11 q ha^{-1}) yield.

Nandana *et al.* (2019) [42] conducted field experiment and reported that retention of crop residue increased total organic carbon (12%) and soil available nutrients available P (16%) followed by available K (12%), DTPA extractable Zn (11%), and available S (6%) over residue removal treatment. A large number of residues are produced in the rice – maize cropping system, which contains a sizeable amount of the major and micronutrients needs to be utilized to meet the demand of crop grown in the systems. The technologies are needed to incorporate stubbles of both the crops in soil and its decomposition process, which enable to release the nutrient during crop growing period and utilized by them. Changes towards large scale mechanization in agricultural production are providing a favorable condition to expand the practice of recurring crop straw to field.

Effect of nutrient management on

Growth of rice

Plant growth components mainly includes comprise of plant height, number of tillers, number of leaves, dry matter production, leaf area and leaf area index etc. which contribute to the growth of the plant and finally the crop.

Banerjee and Pal (2009) [15] reported that growth parameters *viz*. plant height, leaf area index, dry matter accumulation and crop growth rate increased due to application of 100% RDF. It was also mentioned that high doses of nitrogen increased the cell division and various metabolic activities of the plant and thus increased various growth parameters of rice.

Found that higher levels of N, P and K fertilization (200:100:80 kg ha^{-1} N, P and K) increased the plant height, number of tillers hill^{-1}, leaf area, leaf area index and crop growth rate, but specific weight of leaves was greatly reduced. While, dry matter accumulation, relative growth rate and net assimilation rate were not affected by high (200:100:80 N, P and K kg ha^{-1}) and moderate (100:50:40 N, P and K kg ha^{-1}) levels of nutrient application.

Javeed *et al.* (2017) [43] studied the effect of growth, yield and quality of rice (*Oryza sativa* L.) and observed that among different graded levels of N, P and K, application of nitrogen at 60 kg ha^{-1} produced significant maximum growth components (plant height and dry matter production) as well as grain and straw yield than 30 kg or 40 kg N ha^{-1}, but was at par with 50 kg ha^{-1} of N. The uptake of nutrients was also highest due to the application of 60 kg ha^{-1} N.

Yield attributes and yields of rice

Tripathi and Kumar (2010) [44] observed that different level of N, P and K significantly affected the grain production of rice and increasing levels from 100% recommended doses (RDF) of N, P and K to 150% recommended levels of N, P and K increased the grain yield of rice about 4 to 5 q ha^{-1}. The increased in N, P and K dose from 150 to 200% of RDF showed adverse effects on grain yield due to severe lodging of the crop.

Linlin *et al.* (2018) [45] assessed the main effects and interaction effects of rice crop residues, N and P fertilizer on growth of rice and soil properties in a paddy field. The study was included two combinations of crop residues (0 and 2.25 t ha^{-1}) and two N fertilizer levels (120 and 180 kg ha^{-1}) and two P fertilizer levels (37.5 and 67.5 kg ha $^{-1}$). The results confirmed that application of crop residues along with (180 kg N ha $^{-1}$, 67.5 kg P $_2O_5$ ha^{-1} and 67.5 kg K $_2$O ha^{-1}) significantly increased rice grain yield mainly due to improvement in grains per panicle.

N, P and K content and uptake by rice

Gurusamy *et al*. (2007) [46] reported that uptake of nitrogen, phosphorus and potassium was 30.4, 10.2 and 26.3 kg ha^{-1}, respectively, The N and K uptake was equal under both situations at Active Tillering (AT) and Panicle Initiation (PI) but P was accumulated in the stage AT but comparable at PI. Reported application of 75% RDF recorded significantly higher grain yield and uptake of N, P and K by grains.

Kumari *et al*. (2013) [48] revealed that rice grown with 100: 21.8: 20.8 kg NPK ha^{-1} recorded significant maximum N, P and K content of grain and straw.

Javeed *et al.* (2017) [43] results revealed that among different graded levels of N, P & K application of Nitrogen at 60 kg ha^{-1} of rice, the uptake of nutrients was also highest with 60 kg ha^{-1} of N. The nutrients uptake was recorded highest at P_{35} K_{15}

Bora *et al*. (2018) [29] studied that uptake of nitrogen, phosphorus and potassium by rice grain and straw different treatments had a significant effect on nutrient uptake in rice. The highest values of nitrogen, phosphorus and potassium uptake in rice were obtained under N_{120} P_{40} K_{40} + Zn + FYM and N_{120} P_{40} K_{40} + FYM treatments. Higher values of nutrient uptake directly relates to better productivity of crop.

Growth of maize

Hussaini *et al.* (2002) [89] found that application of 180: 40 kg N: P_2O_5 ha^{-1} increased plant height, dry weight plant^{-1}, leaf area index, leaf area, relative growth rate and crop growth rate of maize. Almost similar increases in growth parameters with increasing nutrients levels have been also reported by Arya and Singh (2000) [9].

Jayaprakash *et al.* (2006) [49] obtained higher maize growth due to application of 200 per cent of RDF over 125 and 100 per cent RDF, but it was on par with 175. The highest value of growth parameters with the application @ 250 kg N ha^{-1} was also observed by Rafiq *et al.* (2010) [50].

Verma *et al.* (2006) [51] evaluated the effect of supply of nutrients on productivity of maize in sandy soil of Udaipur. The results indicated that maximum plant height, leaf area index and dry matter were observed with 150 percent N, P and K of recommended levels. The maximum grain (34.15 q ha^{-1}) and stover yield (47.65 q ha^{-1}) was obtained with the application of 150 percent N, P and K.

Reddy *et al.* (2018) [52] studied the effect of different levels of nitrogen and (200, 250 and 300 kg ha^{-1}) and phosphorus (40, 60 and 80 kg ha^{-1}) on the growth and yield of maize. The growth parameters of maize such as the height of the plant, leaf area index and production of dry matter are affected significantly by nitrogen and phosphorus levels at 30, 90 DAS and at harvest in the first year and only by nitrogen levels at all the stages on dry matter production and on leaf area index at 90 DAS in the second year.

Yield attributes and yields of maize

Studied at Agricultural Research Center Dharwad and found more yield of maize grains under 200 percent RDF + 40 kg sulfur ha^{-1} compared to 100 percent RDF + 40 kg sulfur ha^{-1}. Applications of 150 percent RDF produced higher grain yield of maize (52.7 q ha^{-1}) than 100 percent RDF (50.4 q ha^{-1}). The increase in maize grain yield with 150 percent RDF was 4.5 percent over 100 percent RDF. Almost similar increases in grain yield due to nutrient application have been also reported by Daikho (2013) [53].

Hashim *et al.* (2015) [54] observed that 50% recommended dose of fertilizer (20 kg N, 60 kg P_2O_5 and 40kg K_2O h^{-1})+50% recommended nitrogen (120 kg N h^{-1}) through crop residue resulted significantly higher maize grain yield over the control.

Minardi *et al.* (2017) [90] found that the highest yield of maize (corn cob) was obtained through application of green manuring (8.40 t ha^{-1}) followed by manure (6.02 t ha^{-1}) and rice straw (5.87 t ha^{-1}). Application of 50 kg P_2O_5 ha^{-1} gave the yield of 5.76 t ha^{-1}, while, application of 100 kg P_2O_5 ha^{-1} yielded 6.12 t ha^{-1}.

Reddy *et al.* (2018) [52] studied the effect of different levels of nitrogen and (200, 250 and 300 kg ha^{-1}) and phosphorus (40, 60, and 80 kg ha^{-1}) on the growth and yield of maize. The lowest grain and stover yields were obtained with N level 300 kg ha^{-1} and 200 kg ha^{-1} and P level 60 kg ha^{-1} and 40 kg ha^{-1} respectively in maize crop

N, P and K content and uptake by maize

Biradar *et al.* (2012) [26] found that maize requires 26.3, 13.9, 35.8 and 3.4 kg N, P_2O_5, K_2O and S, respectively to produce one tone of grain yield it also removed 130, 120, 320 and 13 grams of Zn, Fe, Mn and Cu to produce one tone grains, respectively removes of micronutrients.

Minardi *et al.* (2017) [90] reported that organic matter and P fertilizer application improved soil fertility status and an increase in P uptake that improved maize yield.

Patel *et al.* (2015) [91] reported significant increase in soil fertility by increasing in fertilizer levels and uptake of nitrogen, phosphorus and potassium significantly increases by applying varying fertilizer doses and tasseling treatments.

Residue management on Process of decomposition

Residues are the materials left in an agricultural field after the crop has been harvested and convert to organic matter by the process of stable aerobic disintegration and a controlled decomposition process. As the remains come in contact with the soil, decay of crop residues begin. The decomposition process is controlled by the interaction of three main components *i.e.* biological processes or soil organisms, the quality of crop residue and the physical and chemical environment. The combination of these components not only determines the rate of decomposition of crop residues, but also the final product of the decomposition process. The quantity of plant materials that are decomposed into the soil is determined by the loss of the dry weight of these plant materials when it submerged in the soil or by the evolution of CO_2 from plant materials, either unlabeled or ^{14}C or ^{13}C. (Kumar and Goh, 2000) [50], residue are managed in different ways, residues can be added to the soil or mixed. The residue in soil contact or different distributions tends to be less in comparison to comparative distribution in soil contact. It is also important to evaluate the effects of management practices, and it has been found that the various quantity of residues into soil contact, such as no–till ploughing and rotovating. The contact degree of incorporating implements between crop residues and soil matrix as defined by the residue incorporate method, affecting decomposition under both natural and experimental conditions (Phongpan and Mosier, 2003 and Qi *et al*. 2014) [56, 57].

Availability of nitrogen

Nielsen *et al.* (2007) [47] suggested that there are many biological and chemical processes during crop residual decomposition. Soil microbes need to feed the carbon in the crop residues and N is required for decomposition. In comparison to N, high concentrations of Carbon, soil microbes will take more time to break organic matter and use more soil N to carry out their work. However, the use of cover crops and crop rotation can help in the creation of healthy soils and micro-organisms which encourage the breakdown of residues.

Availability of phosphorus

Webley and Jones (1971) [58] said that inorganic, organic and microbial phosphorus is the major form presented in the soil. Organisms require phosphorus as a structural component for metabolic activity and for a large number of biochemical compounds. Only phosphorus in the soil solution is available for Plant uptake, but due to immobilization and precipitation in the soil its concentration is usually low. The phosphorus contained in the soil residues added to the soil can increase the total soil phosphorus significantly. The quantity of phosphorus in the solution of the soil depends strongly on the phosphorus released from the soluble phosphorus fraction in the residue of the plant during the decomposition. Inorganic phosphate in soil solution is P form taken up by plants, but this soluble phosphorus is easily absorbed by Al and Fe oxide and hydroxide, clay colloid or immobilized by microbial biomass. On the other hand, the concentration of phosphorus in micro organisms varies depending on its development phase as well as the reliability of the quality. More than 60%

of microbial phosphorus is usually in the form of nucleic acids, acid concentration is 20% in soluble phosphorus esters and 5% in phospho-lipid and this ratio varies depending on the development phase of cells and improvement of residual management and promotion practices.

Singh and Charaya (2010) [59] found that when rice or wheat straw treated with 2.21% urea, 1% single super phosphate separately and in combination and also with *Trichoderma* increases the rate of decomposition, but it was more in the case of urea-treated residues decomposition is fast. However, the combination of urea and single super phosphate increases the rate of decomposition as a result of treatment compared to urea or alone single super phosphate a very good response to urea and single super phosphate treatment and after that mixed straw.

Availability of potassium

Mishra *et al*. (2001) [60] stated that during the decomposition of rice straw, K content decreased from 1.30 to 0.28%. Approximately 79% of the total K of rice in the rice straw was released within 5 weeks after incorporation in the soil, and 95.3% of the straw from K was mineralized by 23 weeks. Apart from this, Singh *et al*. (2005) [61] said that the release of K from rice straw was done at a fast rate within 10 days after incorporation, the available soil K content increased from 50 mg kg^{-1} to 66 mg kg^{-1} K.

Availability of sulphur

Sulfur is an important nutrient for the growth of the crop and its deficiency is exposed to tropical soil by intensive agricultural practices, it is generally accepted that the plant optimizes the S completely as the SO_4 Made by organic mineral deposits: phosphate, sulphates are easily leached. Incorporating crop residues in the soil is a way of decreasing loss of sulphur by leaching. Mineralization of sulfur in soil is done by biological activity (Singh *et al.*, 2005) [61].

Studies of Islam and Dick (1998) [62] indicated that the quantity of SO_4 in the amended soil with crop residues will depend on the type of soil, the nature of crop residues and the timing of decomposition with the addition of crop straw.

Micronutrients

Kang (1988) [92] found that the availability of Zn for various pools, such as exchangeable, soluble in water and weakening of organic materials tightly, was reduced by straw application in soil pH 8.0. Many other workers (Yoon *et al.*, 1975, Dikshit *et al*., 1976, and Nagarajah *et al.*, 1989) [63, 64, 65] have also stated that the application of rice or other crops straw in both the flood and upland soil reduced the concentration of Zn (Saviozzi *et al.*, 1997) [66]. However, no significant impact of crop straw on Zn and Cu material and supply was seen in the soil. Even so, the application of rice husk in rice plants has been found to increase Zn content, probably through its effect on soil pH and exchangeable sodium percentages. It is reported that for production of one tonne rice straw, removes 96, 777, 745, 42, 55 and 4 g ha^{-1} of Z, Fe, Mn, Cu, B and Mo, respectively from the soil (Prasad *et al.*, 1999) [67]. Approximately 50 to 80% of the Zn and Cu can be recycled by the incorporation of rice crops residue. Therefore, crop residues recycling can help to improve the availability of micronutrients in the soil (Prasad and Sinha, 1995) [68].

Effect of crop residue on
Soil fertility

The Long time straw incorporation in soil, improves fertility and productivity of soils. The rice residue incorporation in the soil is the main source of soil organic matter after decomposition in the rice-based cropping systems (Ponnamperuma, 1984) [69]. In soil productivity, plays a major role of soil organic matter because it represents the main source of nutrients. It also affects pH, ions and cation exchange capacity and soil structure. Its level in the soil was used as a general indicator of soil productivity. Plant residues are contributing to annual input to increase the level of organic matter of the soil. Long-term fertility is becoming more relevant in terms of relation management impact on soil organic matter and soil quality in tropical environments. Crop residues, including roots, have become a more common source of organic matter added to the soil in tropical countries, where the use of harvester is increasing (Flinn and Marciano, 1984) [70]. The crop residues are main constituent for nutrient rotation, as straw of most cereal and other crops contains N, P and K (Barnard and Kristoferson, 1985) [16].

Physical properties of soil

Availability of plant residues to soil microbes is of primary importance in the rate of decomposition. Soil particle size can provide different degrees of access, which in turn affects the decomposition rate of the residues as well as the mineralization and immobilization process. Generally, small particles are rapidly decomposed compared to larger particles, because of the increased surface area and better distribution in the soil will increase sensitivity for microbial attack (Jensen, 1994) [71].

The particle size plays an important role in decomposition of residue. Early decomposition (3-17 days) was sharp for small-sized particles (0.06-0.1 cm) than large particles (5 and 10 cm). It was expected that greater accessibility and availability of N were responsible for the higher rate of decomposition witnessed for finely ground residue, while a physical protection of finally ground residues was possibly involved in the observed reverse effect of low C:N ratio (Angers and Recous, 1997) [5]. Sylvia *et al*. (2005) [93] found that clay soil is one of the major soil texture components determining soil erosion and drainage and strongly affects the rate of decomposition of the residue. The clay concentration of soil is positively correlated with aggregate size and aggregate formation and it has been negatively correlated with potential N minerals. Clay soil plays an important role in soil carbon, water and nutrient absorption through the residues of binding plants and chemical reactions between the soil minerals and cations such as ammonium (NH_4^+), thereby reducing residue mass loss.

Chemical Properties of soil

Soil texture can affect the decomposition of plant materials. The decomposition of the crop residues in soil residues with less soil content was much faster because the soil saved organic matter from decomposition. As the amount of clay soil increases, the area of soil surface also increases, resulting in increase in organic C immovability. The role of clay soil in stabilizing organic matter seems more important in warm soils, where decomposition is at high rates (Lade *et al*, 1996) [72].

Optimal C: N ratio for microbial growth is approximately 25 though C: N ratio of crop residues ranges from 20 to 500 depending on plant maturation and species. Plant residues with high C: N ratios (> 40) are very slowly mineralized compared to residues with C: N ratio less than 40. At lower C: N ratio, plant material meets the N requirements of soil microbial population and additional N mineralizes and becomes available for plant uptake (Baldock, 2007) [14].

Sharma *et al.* (2012) [73] reported that after retaining the crop residues in the soil, the lower pH values of the soil solution were recorded between 2 to 6 weeks of transplanting rice. The retention of crop residues on the surface of the soil can reduce soil pH, which adversely affects crop production (Schomberg *et al.*, 1994a) [74]. Yoo *et al.* (1990) [75] noticed a significant increase in pH of flood water with the use of rice straw. Beri *et al*. (1995) [23] and Bellakki *et al*. (1998) [20] did not see any significant impact on the incorporation of crop residues on pH of soil.

The effect of application of plant materials on soil pH depends on the structure of the plant material used. After nitrification, mineralization of N rich compounds produces proton, which leads to acidification of soil. The effects of residues on soil pH seem to be small but the method of residual management can greatly affect the soil reaction (Yan *et al.*, 2016) [76]. The result of Alberto *et al.* (1996) [1] showed that straw incorporation improved organic C, total N, available P and exchangeable K in soil.

Wang *et al.* (2015) [77] said that the total soil organic carbon and N concentration in the top 40 cm soil was statistically higher in straw application of the field than the control by 7.2%, 8.2%, respectively.

Biological properties of soil

Fujii *et al.* (1972) [78] reported that during the initial stage of incubation of rice residue under the condition of waterlogging, obtained high-protein decomposing micro-organisms, after which the population of cellulose-decomposing microorganisms increased. In the C: N ratio of 52:1 in rice straw, the microbial population has been increased as reported by Nugroho and Kuwatsuka (1992) [79]. The regular addition of sufficient amounts of organic materials such as crop residues to the soil leads to the maintenance of microbial biomass Patra *et al.* (1992) [80]. The residue incorporation into the soil leads to increase the bacterial and fungal activities (Beare *et al.*, 1996) [17]. Sidhu and Beri (2005) [81] saw that 5-10 times more aerobic bacteria live in soil treated with crop residues and 1.5 to 11 times more fungi where remnants were burnt or removed from the soil.

Singh *et al.* (2005) [61] said that residue helps for development of microbial activity as well as microbial biomass in the form of nutrients to form substrate for acting. The availability of nutrients such as N, P and S are particularly dependent on microbial biomass and microbial activity, which in turn depends on the supply of organic matter in the soil.

Gaind and Nain (2011) [82] mentioned the decrease in the sample of microbial biomass in the second month's soil sample, and the increase in the third-month soil samples, and again a considerable reduction in soil samples, in 120 days of crop growth was analyzed. The Li and Lin (1993) [83] observed that soil pH affects both nature and microbial size of the population, which ultimately impact residue decomposition.

Effect of residue management on crops

Verma and Pandey (2013) [94] studied two years in rice - based cropping system and reported that uptake of nitrogen by grain and straw was significantly affected by residues management and nutrient application. The maximum nitrogen uptake by grain and straw was recorded under the treatment when rice residue incorporated with 30% additional N, P and K as compared to recommended N, P and K against sowing of succeeding crop without rice residue incorporation + RDF N, P and K and incorporation of rice residue + recommended N, P and K.

Bahadur *et al.* (2015) [10] reported that crop residue is important components of low external input of sustainable agriculture without sacrificing productivity. Crop residue improves the physical, chemical and biological properties of soil. Crop residue increased the crop productivity. Crop Residue can be partially substituting the fertilizer nutrient but not completely replacing them. Crop residue has potential to improve the fertility status of soil.

Stephanie and Kristine (2015) [95] indicated that residue application results in greater soil organic carbon levels compared to complete residue removal. In most comparisons included in analysis, plots on which residues were applied had higher soil carbon stocks than paired plots with no residue application. In reality, some natural variation occurs in soil carbon stocks from plot to plot, contributing to the error in analysis. The lowest amount of residue left in fields in the studies included in analysis was 4 t ha^{-1}. It thus appears that, in the contexts of these studies, leaving 4 t ha^{-1} or more residue in fields increases soil carbon levels compared to complete removal.

Sannathimmappa *et al.* (2015) [84] suggested that application of 75% N, P and K through chemical fertilizers in combination with 25% N, P and K supplied through rice straw with *Trichoderma* 5 kg ha^{-1} was the best nutrient management practice for nutrient uptake in rice, since there was a balanced of nutrients sources of organic and inorganic combination.

Hiel *et al.* (2018) [85] evaluated the effect of the management of crop residue on crop production, soil nitrate, phosphorus, potassium and organic carbon content and uptake through the crops and explained that there was not any effect of crop residue management on the nitrate content, since the effect of fertilization conquered the effect of residue management.

Economics

Bobde *et al. (*1998) [28] working in in Nagpur concluded that supplemental and organic substances with a reduction of 50% in the N & P dosage with the recommended dose and 7.5 t ha^{-1} of the residues provided significantly higher return (11.2 per cent) than the RDF. Dubey and Verma (1999) [96] similarly reported that the highest net returns (Rs 21,505 ha^{-1}) and B:C ratio (1.54) under 50 percent through chemical fertilizers by NPK and 50 percent through organic matter. A component of the sequence, high yields of crops increased overall net returns.

Profitability considers the potential economic gains or loss resulting from observed changes in productivity. In situ incorporation of crop residue during normal tillage before establishment of rice results in no extra cost for managing crop residue provided the normal tillage does not involve more time or energy due to the presence of residue. If cost of land preparation is not altered by the incorporation of residue, then any increase in production can result in net profit for the farmer. Because of potential short-term detrimental effects of anaerobic residue decomposition on the young crop, such as immobilization of N and release of organic acids, the preferred practice is typically to incorporate residue several weeks before establishing crops. Singh and Sharma (2000) [86] found that with increase in nitrogen levels from 0 to 120 kg ha^{-1} increased net returns.

The maximum net return of maize (`20,951 ha^{-1}) and profit cost ratio (2.92) was seen by the application of 150% RDF compared to 100% RDF+10 t FYM ha^{-1} (Kumar *et al*., 2002). Karki and Ashok Kumar (2005) said that the maximum net profit in the application of NPK ha^{-1} and the ratio of B: C of maize was treated at 120: 60: 50 kg ha^{-1}. Hashim, *et al.* (2015) [54] said that 100% RDF applications in maize registered maximum net profit followed by 75% RDF 25% RDN. However, B: C ratio was significantly higher in the ratio of 1.33 and 1.60 in the control than that of other treatments after 100% RDF during 2011 and 2012 respectively.

Raghavendra *et al*. (2016) [87] said that the highest cost of cultivation was 150% RDF and the lowest cost of cultivation, highest return, net return and B:C ratio in maize was recorded under 50% RDF. Between crop residue management practices, without residues recorded the highest net returns and they were equivalent to 2 tons ha^{-1} crop residues in both the years of maize.

However, the highest return was reported with 4.0 t ha^{-1} crop residue and it was statistically similar to all the crop residue management practices, except without crop residue treatment. Crop residue did not show the highest B:C ratio followed by 2.0 t ha^{-1} and 4.0 t h^{-1} crop residue. The lowest B: C ratio was recorded with 6.0 ha^{-1} crop residues.

Mahto *et al*. (2018) [41] found that the application of 100 kg N, 40 kg P_2O_5, 20 kg K_2O along with ZnSO4 @ 25 kg ha^{-1} in rice and 120 kg N, 75 kg P_2O_5, 50 kg K_2O in maize in same plot resulted in significantly higher cost of cultivation (Rs 61670 ha^{-1}), gross return (Rs 187458 ha^{-1}), net return (Rs 125788 ha^{-1}) and benefit: cost ratio (2.47) of the rice - maize cropping system over the remaining nutrient combinations.

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