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Review Article

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The Role of Cereal legume Intercropping in Soil Fertility Management: Review

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Abstract

The objective of this review paper is to organize relevant literatures on roles of cereal-legume intercropping in soil fertility management using the results of researches undertaken in different parts of the world at different times. Relevant materials including journal articles reviews and short communications were used to organize the review entitled roles of cereal-legume intercropping in soil fertility management. This review material can assist researchers who are interested to conduct their research in the areas of intercropping and soil fertility issues. In addition this review helps the practitioners to have a clear understanding on the benefits of intercropping in maintaining soil fertility that highly contributes to crop productivity. Intercropping is a valuable agricultural strategy that allows two or more crops to be grown in the same area at the same time and increases land use efficiency through combination of crops more importantly cereals and legumes. It is the cropping method that enables efficient utilization of resources such as water, soil nutrients, light, and others resulting in higher productivity as compared to mono cropping. Intercropping improves water use and enhances infiltration by intercepting rain drops before they contact the soil surface, minimizing soil erosion which is serious environmental concern and simultaneously posing a threat to food security and human nutrition. Intercropping reduces run offs, soil pH, increases cat ion exchange capacity and soil organic matter. Intercropping also improves the quality and fertility of the soil the through improving the enzymatic activities in the soil. Intercropping improves nutrient availability and uptake by plants and finally boosts yield as shown by various studies conducted across the globe reveals.

Keywords: *Cropping systems; Erosion; Run off; Nutrients; Organic matter*

Background

The objective of this review paper is to unify the roles of Cereal-Legume intercropping for soil fertility management. Legumes enhance soil fertility by fixing atmospheric nitrogen and transforming it from inorganic to organic forms that plants use and can completely or partially replace nitrogen fertilizer (Dwivedi et al., 2015). Intercropping is a valuable agricultural strategy that allows two or more crops to grow in the same area at the same time, increasing land use efficiency (Yu et al., 2015). It is the growing of two or more preferably dissimilar crops simultaneously on the same field that may be of annual crop with annual intercrop; annual crops with perennial intercrops; and perennial crops with perennial intercrops (Eskandari et al., 2009). The intercropping method efficiently utilizes resources such as water, soil nutrients, light, and other factors, resulting in higher productivity. According to Ghanbari et al., (2010a) two crops with distinct heights, canopies, adaptations, and development patterns grow simultaneously with the least amount of competition. The new sustainable crop production systems rely primarily on legumes' symbiotic nitrogen fixation (Ladha and Chakraborty, 2016). Cereals are nutrient-depleting crops that collect nutrients from the higher soil layers (Ali et al., 2012). According to Ladha et al., (2007), soil degradation is evident for loss of the quality and quantity of soil nutrients, as well as physical and biological soil qualities.

Cereal-legume intercropping has been reported to conserve soil and water within particular land forms (Anil et al., 1998), provide stable yield (Lithourgidis et al., 2006). Because of the legume's ability to adapt to disintegrated soils and diminishing soil health, smallholder farmers frequently plant cereal-legume intercropping (Begam et al., 2020). Legume being able to fix atmospheric N in soil improves the soil fertility and reduces the completion of limited soil nutrients within the soil (Fujita and Ofosu-Budu, 1996; Meena et al., 2015b). Legumes are soil-amendment crops with significant soil-health advantages, and they must be an important part of farming systems (Dhakal et al., 2016). On the basis of the advantages of intercropping in terms of resource use, soil fertility management and productivity, this review paper aims at reviewing relevant literatures on their roles for cereal-legume intercropping for soil fertility management.

Materials and Methods

This paper is a review paper. All the data and information included in it are adopted from secondary sources journal articles, reviews and short communications. The review paper was compiled through an exclusive search through different articles, proceedings and Journals and websites for update information. By collecting necessary information from different sources, the review paper was compiled and arranged for better understanding and clarification.

Review of Findings

Role of intercropping in soil and water conservation

Surface runoff and soil erosion are serious environmental concerns, in addition to posing a threat to food security and human nutrition (Fenta et al., 2021). Surface pores are sealed by splash erosion, preventing water from entering the soil and increasing overland flow and related surface erosion (Cerdà et al., 2009). To create management plans for maintaining productivity, cereal (maize)-legume (cowpea) intercropping is advantageous for concurrent income enhancement, crop diversity, and soil preservation (Sharma et al., 2017). Soil water absorption may mitigate the adverse effects of water consumption on soil water retention under intercropping than sole cropping and thereby reduce soil erosion (Wen et al., 2022).

Intercropping cereals with legumes is a great way to reduce soil erosion while ensures crop production (Lithourgidis et al., 2011). When rainfall is abundant, cropping management practices that leave the soil naked for a large portion of the season may allow for significant soil erosion and flow, resulting in barren soils with poor crop performance characteristic. Deep roots also reach deeper into the soil, breaking up hardpans and utilizing moisture and nutrients from deeper in the soil. Shallow roots help to minimize erosion by binding soil particles near the surface. Shallow roots also help to aerate the soil, which improves water retention. Intercropping legumes with cassava resulted in reduced runoff and soil loss

Crop production losses due to erosion in sub Saharan Africa are estimated to vary, although they can be significant on severely degraded soils. In Tanzania and Kenya, for example, erosion has been predicted to reduce maize yields by up to 59 and 66 percent, respectively (Okoba and Sterk, 2010). Cropping systems can also help to prevent soil erosion. Seran and Brintha, (2010) reported that intercropping systems reduce soil erosion by preventing raindrops from striking bare soil, which closes surface pores, prevents water from entering the soil, and increases surface runoff. According to Zougmore et al., (2000), a mixed sorghum and cowpea crop reduced runoff by 20-30% compared to sorghum alone and by 5-10% compared to cowpea alone. (Dass and Sudhishri, 2010) found that mixed farming finger millet with black gram reduced runoff by 17.5 percent and soil loss by 10.6 t ha-1, while mixed cropping finger millet with pigeonpea reduced runoff by 18.0 percent and soil loss by 10.9 t ha-1. Furthermore, when compared to sorghum and cowpea monocultures, intercropping reduced soil loss by more than 50% (Zougmore et al., 2000).

Nutrients availability and uptake under intercropping

Maize-cowpea intercropping boosts nitrogen, phosphate, and potassium content as compared to maize monocultures, according to Ghanbari et al., (2010b). According to Ma et al., (2017), intercropping boosted the soil nutrients availability. In another study, it was reported that intercropping boosted soil organic matter and total nitrogen concentration (Cong et al., 2015b). Intercropping, or enhanced species diversity, has been linked to increased ecosystem productivity and nutrient retention (Brooker et al., 2015).

Oberson et al., (2001) concluded from a field experiment on maize + soybean or maize + cowpea intercropping systems that legume-based cropping systems maintained greater organic and accessible P levels than non-legumes in rotation and also concluded that greater turnover of roots and above ground litter in legume-based intercropping could provide steadier organic inputs and therefore, high P cycling and availability. Rain interception is expected to enhance with multi-layered intercropping canopies, as well as litter fall due to increased productivity and longer water retention, resulting in reduced surface runoff and increased soil nutrients (Lal, 1989).Chalka and Nepalia (2006) discovered that intercropping maize with soybean reduced NPK depletion and increased N absorption(Oberson et al., 2001).In contrary to this, Mucheru-Muna et al., (2010) reported that hastens soil nutrient depletion, especially for phosphorus, due to more effective soil nutrient utilization and increased removal through harvested crops. In intercropping systems, increased nutrient uptake can occur both geographically and temporally (Li et al., 2021). When crops in an intercropping system have peak nutrient demands at various times, spatial nutrient uptake can be increased by increasing root mass, whereas temporal nutrient uptake can be increased by increasing root mass (Kätterer et al., 2011). When compared to solitary cropping, the intercropping technique provides higher and substantial N, P, and K uptake in crops (Tripathi and Kushwaha, 2013), found that when pearl millet was intercropped rather than sole cropped, nutrient uptake in terms of NPK was considerably higher.

Intercropping for Soil Quality

Soil enzyme activity is crucial for soil quality and can indicate changes in metabolic capacity and nutrient cycling as a result of management (Saha et al., 2008). The soil microbial population was affected by the cropping system, and the abundance and community structure of soil bacterial and fungal groups changed as a result of management practice modifications (Acosta-Martinez et al., 2010). According to Ahmad et al., (2013), intercropped treatments had greater invertase, urease, alkaline phosphatase, and catalase activity, the entire growth season of garlic-cotton and wheat-cotton intercropping systems, invertase, urease, catalase, and alkaline phosphatase activities were significantly greater than in cotton monoculture. Intercropping cucumber with onion or garlic increased soil urease and catalase activities, according to Keerthanapriya et al., (2019). According to Han et al., (2013), degraded garlic stalks had a positive impact on soil enzyme activity.

Intercropping on soil properties

Soil physical properties

Leguminous crops promote air circulation, water retention, and buffering constraints by adding organic matter to the soil (SOM). This aids in the balance of soil aggregates, air circulation, water retention, and buffering restrictions, as well as making the soil more cultivable. SOM physically and chemically chelates the soil, strengthening soil aggregation and so stabilizing and resisting disintegration, according to Layek et al., (2018). Grain legume residues with a low C/N ratio breakdown more quickly and produce more SOM, affecting soil aggregation and lowering soil bulk density. According to Ganeshamurthy et al., (2006), adding mung bean Stover to the rice-wheat-mung bean sequence reduced bulk density and hydraulic conductivity. In the agricultural system, intercropping beans with cereal offers clear advantages above results obtained with monoculture, primarily because, during shared growth, the roots of the two crops become entangled with one another and because cereals compete more fiercely for root nutrition {Lai, 2022 #1861}.

Soil Chemical Properties

Legume crops can alter the pH of the soil in the rhizosphere, boosting nutrient accessibility to cereals. Because of proton release from the roots, the soil becomes acidic during legume cultivation. Plants accumulate organic anions as a result of proton release, which, if returned and degraded in the soil, can neutralize soil acidity (Yan et al., 1996).When planted in phosphorus-deficient settings, some plants, such as Vicia faba, use malate and citrate to acidify their rhizosphere, lowering the pH of the growth media dramatically (Weidenhamer and Callaway, 2010).Pulses get more of their nitrogen from the air as diatomic N than from the soil as NO3, which lowers the pH of the soil.

Soil organic matter under intercropping

Plant diversity leads to higher litter diversity. Litter mixing effects were frequently documented in studies modifying litter diversity since mixing litters expedited or hindered decomposition compared to the average breakdown of the mixture components (Hättenschwiler and Jørgensen, 2010).These behaviors are frequently observed when the quality of litter components as a breakdown substrate varies (Wardle et al., 1997). The quantity of litter may affect decomposition, and litter quantity may be linked to plant diversity, especially in the long run, due to positive interactions and feedbacks between variety, nutrient retention, and productivity. Several long-term biodiversity experiments in grassland ecosystems have revealed that species-diverse plots decompose SOM faster than monocultures (Cong et al., 2015a). Intercropping is preferred over monocultures because intercrops contain more aboveground biomass (Lithourgidis et al., 2011) and root biomass (Ghosh et al., 2006). A lower C/N ratio is related with higher breakdown rates in general (Booth et al., 2005). Though there are controversies with regard to organic matter decomposition, intercropping could enhance SOM decomposition as a result of cumulative reduction in the reluctance of SOM.

Intercropping in improvement of soil fertility

The capacity of pulses to re-fertilize soil is well established (Kakraliya et al., 2018);(Bedoussac et al., 2015). Grain legumes could essentially serve as a key role in crop diversification/intensification in different production systems, thanks to their inherent potential of a deep root system, BNF, and, most importantly, their complementarity with cereals and other non-legume crops (Kakraliya et al., 2018; Meena et al.,2015a). Pulses, according to Layek et al., (2018) can aid in reversing the continuous cereal-cereal system's falling production trend by enhancing the soil's chemical, biological, and physical environment. Because all roots have the same architecture and depth under the surface when just one crop is grown, they tend to compete with one another. When compared to maize monocropping, (Vesterager et al., 2008) found that maize-cowpea intercropping is particularly beneficial for N-deficient soil and enhances accessible N, phosphorus, and potassium levels in the soil.

Recent initiatives in Africa to replenish soil fertility have included the use of legumes as an intercrop and/or in rotation to reduce foreign inputs (Sanginga and Woomer, 2009). Soil mineral N content in legume-planted soils may grow due to leakage from nodules where microorganisms living symbiotically within nodules in the root systems of leguminous forage crops reside, and hence soil fertility in intercropping systems may be higher than in monoculture agriculture (Cassman et al., 1998). Legumes help to improve soil fertility by turning inorganic nitrogen into organic forms that plants can consume (Kakraliya et al., 2018). Nitrogen fertilizer can be totally or partially replaced by biological nitrogen fixation. Through the use of legumes, intercropping boosts soil fertility by atmospheric nitrogen fixation (150 tons/year) and soil conservation by providing more ground cover than solitary cropping (Ananthi et al., 2017). Furthermore, because inorganic fertilizers have been linked to environmental problems such as nitrate pollution, legumes grown in intercropping are being considered as a possible alternative to inorganic fertilizers in low-input agro-ecosystems (Ćupina et al., 2011).

As a result of combining legumes with cereals, some nitrogen is provided to the cereal component, as well as some residual nitrogen to the crops that follow (Adu-Gyamfi et al., 2007) return and breakdown of crop waste are the primary sources of other nutrients (Rahman et al., 2009). Crop residues are a valuable source of fertilizer for small-scale farmers, and controlling the fate of nutrients released by crop waste decomposition is a crucial goal for improving cropping system nutrient efficiency.

Role of Intercropping in Nitrogen cycling and loses

Because of competing, complementary, or facilitative interactions, intercropping grain legumes and cereals has the potential to improve the use efficiency of N sources. Several studies have found that competitive interactions between cereals and grain legumes result in a non-proportional distribution of soil N sources in intercrops of cereals and grain legumes (Jensen et al., 2020).Cereals typically acquire a significantly bigger proportion of soil N than the intercrop, and the grain legume will compensate for its reduced part of soil N by fixing atmospheric N2 (Bedoussac and Justes 2010; Naudin et al.,2010). The advantage of complementarity in N source usage will lessen when soil N availability or fertilization increases, as will the distance between intercropped species (from mixed to strip intercropping). This is because the legume will take up more soil N, reducing the symbiotic N2 fixation (Jensen et al., 2020; Bedoussac and Justes 2010; Naudin et al., 2010).When compared to solitary crops, intercropping provides extra benefits such as lower (10–16%) nitrate leaching (Hauggaard-Nielsen et al., 2003). Studies have shown that intercropping reduces N2O emissions when compared to sole crops (Pappa et al., 2011; Senbayram et al.,2015).

Conclusion

This review focused on cereal legume intercropping which is a cropping method that has various benefits in soil fertility management by lowering runoffs through covering the open ground in between crop rows and enhancing all of the soil's physical and chemical qualities. Intercropping reduces runoffs, reduces soil pH, boosts cat ion exchange capacity and increases the soil organic matter. Cereal-legume intercropping is a crop production strategy that improves the soil's quality and fertility by increasing enzyme activities in the soil. Intercropping makes the bulk of the plant nutrients in the soil available to the plants. In sub Saharan Africa, researches on cereal-legume intercropping systems has shown improvements in soil fertility and crop yields, particularly for cereal crops, which are the primary food crop for smallholder farmers. The intercropping method of crop production improves the soil fertility by appropriate combination of legume cops that fix atmospheric nitrogen in to the usable forms by plants. The ratio to be used in the intercropping system is based on the decision of the producer either to use the additive or the replacement series of the intercropping system. This could probably relay on fertility status of his soil that may require more legumes to fix more nitrogen that his cereal component crop requires.

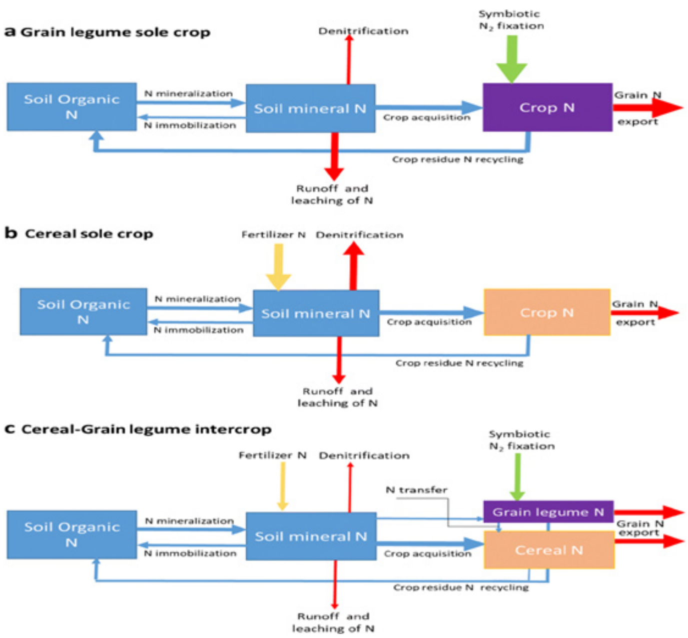

Figure 1: *Conceptual presentation of the most important N cycle processes.*

Source : (Jensen et al., 2020).

Figure 1 clearly shows that intercropping is more beneficial than monocropping by reducing runoff, denitrification and leaching which are higher under monocropping system.

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