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Review Article

Role of Crop Rotation for Organic Farming and Soil Fertility for Crop Production

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Abstract

This review conducted to summarizes crop management research-based evidence generated over the last years. Research outputs revealed that crop rotation has significant response on soil fertility improved by soil chemical properties such as soil P^H, nitrogen (N), available phosphorus (P), organic matter and cation exchange capacity (CEC.).

KeyWords: Crop Rotation; Soil P^H; Nitrogen; Phosphorus; Cation Exchange Capacity; Organic Carbon

Introduction

Food production in Ethiopia is moving at a far much slower pace than population growth, leading to continued declines in its already low food production per capita. Ethiopian agriculture is still heavily dependent on the natural soil fertility, terrain, climate, and water availability. In this region soil nutrient balance aggravated through time to time and it leads low crop yield. Nutrient depletion rates are aggravated in Ethiopia by high erosion, biomass and animal manure removal from farm plots, limited application of mineral and organic fertilizers, land degradation, recurrent drought, over grazing and monocropping for the major crops in the area Teklu et al. (2006), [1,2]. In Ethiopia, chemical fertilizers (diammonium phosphate (DAP) and urea) which are most common applied for the last five decades to obtain optimum crop yields. It is apparent that, inorganic fertilizers have a high concentration of nutrients that are rapidly available for plant uptake. Relatively small quantities of inorganic fertilizers are required, and transport and application costs are low. Through time to time, a wide range of inorganic fertilizers are required to maintain soil fertility and crop yield. Farmers are aware that without inorganic fertilizers the productivity of their crops will drop, and soil nutrient levels will decline rapidly Waswa et al. (2007). In contrast, sufficient mineral fertilizers are not available at the right times during cropping season, and this is attributed to high transaction costs Nyamangara et al. (2009). Inorganic fertilizers also contribute to eutrophication (fertilization of surface waters), which results in explosive growth of algae resulting in disruptive changes to biological equilibrium [3]. In the middle of the 19th century, organic material in the form of manure was the only recognized source of plant nutrients added to the soil before the introduction of chemical fertilizers [4]. Research finding showed that a positive correlation between the application of manure and inorganic N-fertilizer on soil organic carbon (SOC), bulk density, macro-aggregate stability, and aggregate protected carbon Dunjana, et al. (2012).

Manure is known to increase crop yield by its favorable effect on physical, chemical, and biological factors that determines the productivity and fertility status of soil and supply nutrients in the readily available form to plants. For instance, 1 ton of high-quality cattle manure can contain up to 23 kg of nitrogen, 11 kg of phosphorus and 6 kg of potassium as evidenced by Vasundhara (2006), Tennakoon, et al. (2003), found the nutrient content of manure to be between 1.2-1.8; 0.4-0.6 and 1.1-1.9 per cent of N, P, K respectively whereas Bhanuvally [4] reports that FYM contains approximately 0.5, 0.2 and 0.5 per cent of N, P_2O_5 and K_2O, respectively. In a different way of improving soil fertility is crop rotation. It is the practice of growing a sequence of different crops on the same piece of land. Long-term studies indicate that crop rotation, in conjunction with other fertility management practices, is fundamental to long-term agricultural productivity and sustainability [5,6]. It plays great role for improving soil physical, chemical and biological characteristics Edesi, et al. (2012). In any case, the effect of rotation on soil fertility is not permanent and mainly depends on managing system, local soil and weather conditions Głąb, et al. (2013).

Most of the crop rotation a shallow-rooted crop like wheat, barley and legumes that are light feeders may be followed by a deeper-rooted crop like maize, potatoes, vegetables, and soybeans to recover nutrients that were unused by the shallow feeders and may have leached by irrigation or rainfall to lower depths in the soil profile. Conversely, a deep-rooted heavy feeder may be followed by a shallow-rooted light feeder to scavenge nutrients that may remain after heavy applications of nutrients Ilumäe, et al. (2009), Tein, et al. (2014), [7]. Objective of the Review: this study is to review and summarized the research output of crop rotation for soil fertility by improving soil chemical, physical and biological properties.

Methodology

Commencing of this review was collected from different available research findings from different research journals. References were also made to documents of national statistics and progress reports of research centers. Then, a detailed literature search was carried out using web of science, Google scholars and open access journals search. Papers selection was made through specific searches for appropriate articles on crop rotation and soil fertility studies in the world.

Results and Discussion

Effect of Crop rotation on Soil Chemical Properties

Crop rotation has improved some of Soil chemical properties like soil P^H, total nitrogen, Available Phosphorus, organic carbon, potassium, and Cation exchange capacity.

a. Soil P^H : Geisseler, et al. (2014), [8,9] showed that cereal-legumes crop rotation cycles, soil P^H changed in plots applied with manure but did not change in inorganic fertilizers .It is the principal factor of plant nutrient up take that are easily available at higher rates in weak acid Rahman and Ranamukhaarachchi [10] and promotes fungal activity soil P^H less than 5.5 also at higher levels makes bacteria more abundant Troll denier (1971). Bacterial growth rates are generally more sensitive to low P^H than fungal growth rates Walse et al. (1998). Microbial biomass and lignin decomposition appears to be not significantly affected by soil acidity at P^H range of 4.5-6.5 [11]. However, in acidic P^H less than 4.5, microbial activity as well as nutrient turnover is greatly reduced [12].

b. Total Nitrogen: Nitrogen is an essential nutrient for plant growth, chlorophyll and protein formation. Nitrogen (N) exists in the soils in two major forms, organic and inorganic N and total N is the sum of the inorganic and organic components of N. More than 90% of the N in soils is in the organic form e.g., amino acids and amino sugars. The inorganic form of nitrogen in the soil is composed of NH_3-N; NH_4-N; NO_3-N, and NO_2-N and their concentrations may vary considerably depending upon several factors, including the application of N fertilizers. Thus, plant available N is made up of the inorganic components of NH_4 + or NO_3^-. Since soil N is mostly organic in nature, N concentrations in soil increase with increased organic matter contents [13].

Legumes are of special interest in organic crop rotations because of their ability to add nitrogen to the system (for example, alfalfa, faba bean and soya bean) or as a green manure (for example, vetch or clover) [14], Talgre et al. (2011). Specialized bacteria (*Rhizobium spp*.) associated with the roots of legumes convert atmospheric nitrogen (N_2 gas) into plant-available nitrogen. The amount of N fixed by this association between bacteria and legumes varies with plant species and variety, soil type, climate, crop management, and length of time the crop is grown. When used strategically in a rotation, legumes provide N to the subsequent crop. There is considerable research on the significant impact of legumes on the amount of N that a legume crop contributes to following crops depends on the amount of N fixed, the maturity of the legume when it is killed or incorporated into the soil, whether the entire plant or only the root system remains in the field, and the environmental conditions that govern the rate of decomposition and farming system [15]. Researchers estimate that from 40 to 75% of the total nitrogen contained in a legume cover crop is available in the soil for subsequent crops and cereals grown after legumes usually take up approximately 15 to 20% of legume [16,14].

c. Available Phosphorus (P): Phosphorus is one of essential macro- nutrients required for plant growth Ragothama [17] and it exists in the soil in both organic and inorganic. It involved in any process in plant to convert solar energy into the chemical energy needed for the synthesis of sugars, starches, and proteins Vance et al. (2003). Phosphorus is the least accessible macronutrient and hence most frequently deficient nutrient in most agricultural soils because of its low availability and its poor recovery from the applied fertilizers. Phosphorus dynamics can be influence by cropping intensification and diversification in cropping systems Grant, et al. (2002). Experiment was conducted to evaluate on the effect of cropping system and fertilizer management on P in two long-term rotations, the result showed that continuous cropping without fertilizer application faced the greatest reduction of soil phosphorous [18]. However, when continuous cropping was combined with the addition of N and P fertilizers, there was a positive effect of cropping on P availability [19].

Moreover, other field experiment was conducted to evaluate the effect of the integrated use of manure and mineral fertilizers on soil chemical properties in Ethiopia showed significant increases in available P [20]. In another study by [21,22] a pot experiment was conducted to compare different organic manures with NPK fertilizer for improvement of chemical properties of acid soil from farmer's fields and nutrient depleted soil from a research field Station. Results showed that application of different types of organic manures enhanced soil organic C, total N, available P, exchangeable K and CEC better than NPK fertilizer in both soils. This indicates that organic manures are better at enhancing soil chemical properties as compared with inorganic fertilizers. Inorganic fertilizers showed low availability of Phosphorous is due to the fact that it readily forms insoluble complexes with Cation such as aluminum and iron under acidic soil condition and with calcium and magnesium under alkaline soil conditions whereas the poor P fertilizer recovery is due to the fact that the P applied in the form of fertilizers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations Vance et al. (2003), [23].

d. **Potassium**: Potassium is a mineral nutrient plants require in the largest amounts that involved in photosynthesis, sugar transport, water and nutrient movement, protein synthesis and starch formation Zublena (1997). It also helps to improve disease resistance, tolerance to water stress, winter hardiness, tolerance to plant pests and uptake efficiency of other nutrients. Experiments were observed in a study with different cropping systems that the exchangeable K in soils increased after potato, maize and groundnut crops whereas, it decreased after rice and jute cropping systems [24] and a significant decrease in K release due to continuous cropping Srinivasa et al. (1999). Potato requires high amount of K for tuber bulking BARC [25]. Recycling of crop residues or applications of high dose K fertilizer may provide a long-term sustainability to cropping systems Singh et al. (2002). In contradictory, other research revealed that cropping systems had no significant effects on K content in soil [26]. According to Zublena (1997), K removal by crops under good growing conditions is usually high and is often three to four times that of P and is equal to that of N. Proper K management requires a thorough understanding of soil K behavior and of the various K inputs and outputs of cropping systems Hoa (2002).

e. **Soil Organic Carbon (SOC)**: Soil organic carbon from soil organic matter is a key indicator of the soil fertility. Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and undergoes decomposition. It serves numerous functions as it acts as a rotate nutrient fund since it is formed mainly from plant residues and the residues contain essential plant nutrients. Therefore, accumulated organic matter is a storehouse of plant nutrients and holds nutrients in a plant available form. Apart from acting as an agent to improve soil structure, lowering bulk density, increasing Cation exchange capacity, improving water holding capacity and minimizes erosion West, et al. (2002) Varvel, et al. (2010). Soil organic matter (SOM) plays a major role in moisture retention and contributes to the physical, chemical and biological properties of the soil. Studies indicate that soil physical, chemical and biological properties can sustainably be improved through the improvement of SOM like in the application of crop rotation and addition of manure [27-29, 21].

On the other hand, a 19 -year long- term experiment was conducted to evaluate the combined application of crop rotation with manure and inorganic fertilizer showed that significant result on soil organic carbon (SOC) dynamic and soil physical properties Yang, et al. (2011). Furthermore, an eleven-year study conducted to investigate the long-term effects of applied cover crop under crop rotation with organic manures and inorganic fertilizers on yield and soil fertility in a wheat/rice cropping pattern indicated that percent SOM was reduced (19 to 13%) with inorganic fertilizers and increased (7 to 39%) with organic manures [9]. Thus, from the study we note the importance of combining inorganic fertilizers with organic manures so as to improve SOM concentrations and sole chemical fertilizer application has a negative impact on the SOM available in the soil.

f. **Cation Exchange Capacity (CEC)**: The Cation exchange capacity (CEC) is the ability of soil to hold plant nutrients. Increasing the organic matter content of any soil will help to increase the CEC since it also holds Cation like the clays. Yilmaz, et al. (2010), [30] report that the application of crop rotation and manure resulted in significant increase in CEC and the increase was associated with rise in organic matter content. Similarly, in a study conducted to compare the effect of crop rotation with organic manures and chemical fertilizers on soil properties [21,31] reported that application of different crop rotation with organic manures enhanced CEC better than the NPK fertilizers.

Effect of Crop rotation on Soil Physical Properties

Soil physical properties play a critical role in creating favorable conditions for crop growth and soil quality. [32] found that the effects of cropping systems on soil physical properties are often related to changes in SOM. Some research findings proved that the addition of soil organic matter in cropping systems increased organic carbon, moisture retention capacity and infiltration rate of the surface soil, porosity while decrease bulk density, that is important indicators of air and water movement in the soil and restrictions to root growth, by incorporating a less dense material and improving aggregate stability Lal (2004), [33]. Furthermore, researchers were reported that higher bulk density values for continuous cereal cropping systems had higher bulk density compared that cereal-legumes rotation systems Karlen, et al. [5, 34] reported that bulk density was 5% greater after 8 years under a corn-soybean rotation compared to continuous corn due to a greater aggregate stability from the addition of soil organic matter under continuous corn. However, several other studies report no effect on bulk density due to the cropping system Huggins et al. (2007), [35, 36]. In another way, application of organic fertilizer such as manure under crop rotation has been shown by many studies to improve the soil physical properties by reducing the bulk density, increasing the water holding capacity and improving the soil structure and infiltration rates and soil porosity [33, 37], Gopinath, et al. (2009) Guo, et al. (2016).

Effect of Crop rotation on Soil Biological Properties

Soil microbial biomass is a small, but significant for decomposition of organic materials and bring to bears key roles in soil fertility and nutrient cycling in agricultural ecosystems [38]. Although, it comprises 2–5% of soil carbon and 1-5% of soil N Smith, et al. (1990) and has a double function in the soil. Firstly, it helps in the transformation of all organic materials that enter the soil and secondly, acts as a dynamic pool containing appreciable reserves of carbon, nitrogen, phosphorus(P) and sulfur (S) [39]. Any changes in the amount of the microbial biomass affect the cycling of N, P and S and their availability to plants Saffigna, et al. (1989), Friedel, et al. (1996). Therefore, measurement of the contents of C, N and other nutrients in the microbial biomass is important to understanding of these fundamental processes Harris et al. (1997).

Studies have shown that soils under crop rotations system usually have greater microbial biomass than soils under monoculture systems Granatstein, et al. (1987) Moore, et al. (2000). The positive effect of crop rotation on SMB has been related to higher C inputs and diversity of plant residues returned to soils Biederbeck, et al. (1984), Robinson, et al. (1996). Moreover, many experiments have found a negative effect of nitrogen-based fertilizers on soil microbial communities. Repeated application of inorganic fertilizers (especially N based fertilizers) decreases the soil P^H [9], Geisseler, et al. (2014), which, in turn, can reduce the nutrient availability and soil microbial biomass Biederbeck, et al. (1984), Ladd, et al. (1994), Bardgett, et al. (1999), [40] and can also change the microbial community composition de Vries, et al. (2006). However, Omay, et al. (1997), Singh, et al. (1993) Geisseler, et al. (2014) concluded that soils fertilized with N had higher microbial population than the same soils without fertilizer addition based on long-term trials around the world. A high microbial biomass C to microbial biomass N ratio indicates that the microbial biomass contains a higher proportion of fungi, whereas a low value suggests that bacteria predominate in the microbial population Campbell, et al. (1991).

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Declaration of interest's statement

The authors declare no conflict of interest

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