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An assessment of Organic and Conventional Farming Practices for Yield, Pest Management and Soil Health

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

This study contrasts and compares conventional and organic farming. The purpose of the study is to assess the effectiveness and impact of each practice before deciding on the best crop-growing approach. Despite their agricultural systems can be categorized as conventional or sustainable depending on the techniques employed. Organic farming which cultivates a range of crops without the use of synthetic manures, the agricultural method that is most sustainable. While producing enough food, organic farming improves soil composition and supports biodiversity by relying on ecosystem services. The review compares the long-term effects of conventional and alternative organic farming practices on yield in which in short term organic yields were found to be 19.2% lower than conventional yield while in long term yields were lower in conventional systems by 31%

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and 50%, respectively, due to the long-term improvement in soil health. In soil health point of view long term practices of organic farming improves physical, chemical and biological properties of soil by increase soil carbon stock by 12 %, more nutrient release and microbial activity. Pest management is effectively controlled by crop rotation, increase beneficial population of pest in organic farming which reduce the dependency on chemical pesticides and maintain the sustainability of soil health and ecology. As a result, organic farming methods are being evaluated in a large number of research worldwide as an alternative due to their better physical, chemical and biological qualities than conventional farming methods.

Keywords: Organic farming; conventional farming; soil properties; pest management.

1. INTRODUCTION

In recent decades, agricultural research has grappled with the challenge of developing sustainable methods to meet the increasing food demands of a growing global population amid changing climatic conditions. The Sustainable Development Goals (SDGs) were established to address these issues, offering two dominant narratives for achieving sustainable agriculture: incremental improvements in conventional farming practices and transformative shifts towards agroecological principles. Organic farming has emerged as a synthesis of these approaches, integrating natural inputs and agroecological practices to promote sustainability. Organic farming utilizes livestock manure, natural plant residues and diverse plant species to close nutrient cycles within agricultural systems, minimizing external inputs and fostering a natural feedback loop for soil fertilization. This contrasts with conventional farming, which relies heavily on synthetic inputs like chemical fertilizers, pesticides and herbicides to maximize yields through intensive cultivation and pest control. The advantages of organic farming, such as improved soil health and reduced environmental impact, have led to its widespread adoption, particularly in Europe, where consumer demand for organic products has surged. Organic practices focus on enhancing soil fertility and biodiversity, emphasizing the use of organic and bio-based materials while eschewing synthetic substances to mitigate soil pollution and promote sustainable agriculture.

Organic manures play a crucial role in enhancing soil quality and crop output, contributing to agri-environmental health by improving soil properties, nutrient content and microbial activity. Examples of organic nutrient sources include green manures, sewage sludge, press mud, farmyard manure and poultry litter. By prioritizing soil health and reducing reliance on harmful chemicals, organic farming practices strive to create economically, environmentally and socially sustainable agricultural systems.

1.1 Conventional Versus Organic Farming

The debate between conventional and organic farming revolves around maximizing positive aspects while mitigating negatives. Conventional farming yields more crops with fewer laborers but poses uncertain and potentially harmful effects, prompting caution. Organic farming rooted in natural principles, emphasizes system health and employs ancient practices like crop rotations and composting. While conventional methods use chemical interventions, organic farming prioritizes biodiversity and soil health by the use of organic manure. Conventional agriculture contributes to greenhouse gas emissions and health issues, while organic farming reduces carbon emissions, enhances soil health, and fosters cleaner ecosystems. This review aims to impartially assess the impact of both methods on soil health through empirical research and theoretical frameworks to inform sustainable agricultural decisions.

2. REVIEW WORK DONE

2.1 Yield

In research spearheaded by Riahi et al. [1] noted that traditional agricultural methods led to greater marketable yield of tomato fruit (55.62 t ha^{-1}) in comparison to organic systems (34.63 t ha^{-1}). Similarly, according to Pimentel et al. [2] initial corn grain yields in the first five years were higher in conventional systems (5903 kg ha^{-1}) compared to organic systems (4483 kg ha^{-1}) due to higher nutrient requirement by the corn crop which is fulfilled by fertilizers in short time. However, after the transitional period (Years 1-5), corn grain yields equalized between the two systems, reaching 6451 kg ha^{-1} under normal rainfall conditions because continuous application of organic manures in the field increase soil organic carbon which enhance the yield of crop. During drought seasons, corn and soybean yields were lower in conventional systems by 31% and 50%, respectively, due to the long-term improvement in soil health. Cavigelli et al. [3] described that organic corn yield experienced an increase with crop rotation but remained 41–24% lower than conventional corn yield. Soybean yield exhibited a 19% decrease in organic systems while wheat yield was comparable between the two systems, averaging 4.09 t ha^{-1}. Walia et al. [4] discovered that the application of different organic sources (FYM + vermicompost + nonedible oil cake) + intercropping or trap crop recorded sustainable yields in maize and potato due to less pest and disease incidence, while 50% recommended NPK + 50% N as FYM/crop residues/composts recorded higher sustainable yield in onion under the maize-potato-onion cropping system. Sharma et al. [5] admitted that the application of FYM gave significantly higher grain and straw yield of wheat crop, whereas the application of 100% RDF gave higher grain and stover yield in maize crop during a ten-year experiment.

In systematic review and synthesis conducted by Ponisio et al. [6] organic yields were found to be 19.2% lower than conventional yields representing a smaller yield gap than previously reported. The use of multi-cropping and crop rotation in organic systems were identified as factors contributing to the reduction in the yield gap because crop rotation reduce pest and disease incidence in the field.

2.2 Soil Physical Properties

Continuous application of organic materials is noted to decrease compaction, bulk density and penetration resistance, offering more favorable physical properties compared to conventionally fertilized systems in the surface soil by Chen et al. [7] organic materials maintain macro and microporosity in the soil which improve physical properties. Quist et al. [8] examined the effects of different farming practices on soil physical and hydraulic properties. They observed a 3% reduction in bulk density in the surface layer under alternative management practices (1.39 Mg m-3) compared to conventional practices (1.43 Mg m-3). In a study focusing on basmati rice farming in North India, Sihi et al. [9] found that organic practices led to lower bulk density (1.26 and 1.31 Mg m^{-3} in organic and conventional farming, respectively). Patra et al. [10] explored in seven years of experiment that application of organic sources FYM, dhaincha and neemcake + *Azospirillum* + PSB gave higher water holding capacity and lower bulk density of soil by maintaining balance proportion of macro and micropores while there is no change in bulk density of inorganic treatment (100% RDF) after rice-tomato-okra cropping sequence. Velmourougane [11] observed in long term experiment that organic management system (FYM) gave significantly higher water holding capacity and lower bulk density of soil comparison to conventional management system in coffee farming. The infiltration rate was 6-10 times higher in organic soils than in conventionally managed soils, according to a study done by Fueki et al. [12]. Das et al. [13] stated that similar findings for north-east India with an infiltration rate ranging from 3.18 cm hr^{-1} in conventional fields to 17.69 cm hr^{-1} in organic fields. Application of organic manure improve soil structure and porosity of soil which enhance the infiltration of the soil.

2.3 Soil Chemical Characteristics

After a span of 12 years, the organic orchard experienced a 32% increase in soil organic carbon (SOC) sequestration, along with notably higher diffusion coefficients and reduced production and emission of nitrous oxide (N_2O) compared to the conventional, integrated orchard noted by Deurer et al. [14] Studies by Marriott and Wander [15] and Fortuna et al. [16] underscore the enrichment of soil particulate organic carbon (POMC) under organic management, surpassing conventional practices by 30 to 40%. Addition of organic matter in the soil enhance soil organic carbon stock which maintain the sustainability of soil in long term.

In comparative study of organic and conventional treatments of organic manure recorded highest organic carbon in *Gliricidia* by Manjappa, [17]. Different fractions of soil organic carbon respond differentially to land use and management practicesas indicated by various studies (Degryzeet al.,[18]; Malhi et al.,[19]; Benbiet al., [20). Benbiet al. [20,21] observed significantly higher concentrations of particulate organic carbon (POC) in organically amended plots under a rice-wheat system particularly when compared to those receiving only fertilizer nitrogen. Moreover, the addition of farmyard manure (FYM) alone or in combination with rice straw resulted in substantial enlargement of the light fraction organic carbon (LFOC) pool and the heavy fraction organic carbon (HFOC) pool with negligible effects on mineral-associated organic carbon (MOC). Highest available nitrogen and phosphorus and potash were recorded in organic treatments than conventional in long term experiment (Manjappa, [17]) Patel et al.[22] analyzed the available major and micro nutrient status in soil after harvest of pit planted sugarcane and established that application of vermicompost (as equivalent to 50% RDN) + Castor cake (as equivalent to 50% RDN) in sugarcane crop significantly increased available nutrient (N, P, K, Fe, Mn, Zn, Cu) status of soil after harvest of the crop as compared to 100% RDF application. Vermicompost decomposition in soil release some chemicals which solublize the nutrient present in the soil.

The combined approach of retaining crop residues, minimizing soil disturbance, and incorporating nitrogen-fixing cover crops has been shown to effectively decrease nitrous oxide (N_2O) emissions while simultaneously enhancing carbon (C) accumulation in soil. Additionally, the introduction of nitrogen-fixing cover crops has been found to further boost carbon sequestration over the initial two decades by Lugato et al. [23]. The utilization of farmyard manure (FYM) at a rate of 20 t ha^{-1} hectare has resulted in enhancements in soil organic carbon content, carbon stock, microbial biomass carbon and dehydrogenase activity within *Jatropha curcas* plantations, as reported by Anand et al. [24]

2.4 Soil Biological Properties

Okur et al. [25] underscored that soil organic carbon (SOC) and microbial biomass carbon along with the activities of protease, urease, alkaline phosphatase and dehydrogenase were significantly elevated in organic farming systems relative to conventional systems due to the robust growth of microorganisms activating various enzyme cofactors. Esperschutz [26] analyzed microbial communities in a long-term field experiment finding higher concentrations of phospholipid fatty acids in organic systems indicative of a clear impact on microbial biomass. Gajda et al. [27] examined increased microbial activity under organic farming through the measurement of fluorescein diacetate hydrolysis. Maharjan et al. [28] studied the impact of land use and management practices on microbial biomass and enzyme activities demonstrating significantly higher organic carbon and nitrogen contents, as well as microbial biomass in organic farming top soil compared to conventional farming. Ramesh et al. [29] conducted a comparative study of soil health under conventional and organic farming revealing that microbial biomass and enzyme status (alkaline phosphatase and dehydrogenase) showed improvement with the organic farming system compared to conventional farming because organic carbon provide energy to microorganism for their growth.

Wu et al. [30] reported distinct microbial profiles and higher microbial activity and diversity in organically managed soils compared to conventional ones. Kobierski et al. [31] reported in sixteen years experiment that the value of biological index of soil fertility, soil activity and enzymatic activities were significantly higher in ecological farming over conventional farming. Babu et al. [32] disclosed that enzymatic activities (dehydrogenase and phosphatase) were consistently higher in the surface layer of soils subjected to organic farming for various time periods.Venketash et al. [33] reported in nine-year experiment that organic nutrient management (crop residues + biofertilizers + farmyard manure) gave significantly higher soil microbial biomass carbon comparison to inorganic nutrient management (NPKZnB). Organic N (FYM + vermicompost + nonedible oil cake) + intercropping or trap crop recorded higher phosphatase, dehydrogenase enzymatic activity in maize and potato than chemical fertilzers (Wallia et al. [4]). Jegoda et al. [34] observed that application of Jivamrut as soil application + Panchgavya as foliar application significantly increased bacterial count (*Rhizobium* and PSB). Comparing the organic management system (1.35×10^{10} gene copies g^{-1} soil) to the conventional system (1.04×10^{10} gene copies g^{-1} soil), soil bacterial counts considerably increased (Henneronet al. [35].

Overall numerous studies suggest that organic farming practices exert a positive influence on soil microbes enhancing diversity and improving functions like nutrient cycling and antagonistic potential. Most notably soil microbial populations, enzyme activities, soil respiration and earthworm numbers or activity tend to be higher in organic practices compared to those using synthetic inorganic fertilizers. While there are small differences in microbial diversity evidence supports greater bacterial, actinomycetes and fungal abundance and activity under organic management. Aher et al. [36] found significantly higher soil organic carbon and enzyme activities in plots managed with organic practices compared to conventional practices. In conclusion, the overall trend from the reviewed literature indicates that organic farming positively influences microbial populations in the soil including beneficial microbes such as *Rhizobium*, *Azotobacter*, phosphate-solubilizing bacteria, among others.

2.5 Pest Management

In a study by Liu et al. [37] indicate that the incidence of Southern blight in tomato crops was significantly lower when organic fertility amendments were used compared to mineral fertilizer. The disease progression rate was also reduced with organic amendments. Another study by Liu et al. [38] reported a higher final incidence of Phytophthora capsici in soils with rye-vetch green manure compared to other organic amendments and synthetic fertilizer. A meta-analysis by Tuck et al. [39] showed that arthropods, birds and microbes exhibited a significant positive response to organic farming, leading to a 33% increase in biodiversity compared to conventional practices. Clifton et al. [40] observed a greater occurrence of entomopathogenic fungi in organically farmed soils with significantly higher abundance of Metarhizium anisopliae colony forming units (CFU) compared to conventional systems. Feber et al. [41] noted that organic systems collected 77% more individuals and 36% more hunting spider species compared to conventional farming. Overall, these studies highlight the benefits of organic farming practices in reducing disease incidence, promoting biodiversity and influencing the abundance of beneficial organisms in agricultural systems.

3. CONCLUSION

In conclusion the comparative study of organic and conventional farming methods has provided valuable insights into their impact on yield, soil health and pest management. The findings reveal that organic farming while often associated with lower yields compared to conventional methods, offers a sustainable and environmentally friendly approach in longer term. Organic farming promotes soil health by enhancing soil properties like increase soil organic carbon, reduce bulk density, increase microbial diversity and nutrient content. This contributes to long-term sustainability and resilience against environmental stressors. Furthermore, the review indicates that organic farming practices can effectively manage pests through natural means such as companion planting, biological control and crop rotation. While conventional farming may initially demonstrate higher yields the long-term consequences on soil health and the environment warrant careful consideration. The organic approach although posing challenges in yield consistency, fosters ecological balance, enhances biodiversity and promotes sustainable agriculture. In light of these findings a balanced and integrated approach that incorporates the strengths of both organic and conventional farming methods could be considered. This could involve adopting agroecological principles within conventional systems to improve sustainability reduce environmental impact and ensure food security for future generations. Overall, this comparative study underscores the importance of moving towards more sustainable agricultural practices that prioritize the health of both ecosystems and human consumers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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