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Review of Changes in Soil Chemical and Biological Characteristics When Farming Practices Switch from Conventional to Organic

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ABSTRACT

Although traditional farming has played an important role in increasing food and fiber yield to meet human demands, but it has relied heavily on synthetic fertilizers, pesticides, and herbicides. Many environmental (viz., reduction in biodiversity) and public health (viz., environmental pollution, soil health) issues have been raised by certain traditional farming practices and associated chemical inputs. Therefore, it is increasingly felt that the modern system of farming is becoming unsustainable as evidenced by declining crop productivities, damage to environment, chemical contaminations. So, the necessity of having an alternative agriculture method which can function in an eco-friendly manner while sustaining crop productivity. Environmental, economic and social concerns have increased the need for an alternative to conventional agriculture. This review examines the changes in soil chemical like soil organic carbon, nitrogen and biological properties like microbial biomass, soil enzymatic activities throughout the "transition period", which is the time between the start of the conversion process and the producer obtaining full organic certification.

Keywords Convention farming, Transition period, Organic farming, Microbial biomass.

INTRODUCTION

The traditional knowledge and practices passed down from generation to generation in Indian agriculture could not generate enough to sustain the growing population. The Green Revolution (GR) accomplished these hopes by transforming India from a food importer to a food exporter. However, the achievement came at the expense of ecology and the environment, as well as the well-being of the people. The origins of GR are frequently linked to Norman Borlaug (American Agronomist), who created disease resistant high yielding wheat cultivars while doing research in Mexico. Because of the success of GR in Mexico, its innovations extended throughout the world in the 1950s and 1960s. In 1965, the Indian government decided to take a big step toward improving agricultural conditions. Thus, under the direction of Dr. M.S. Swaminathan, GR was implemented primarily in areas of Punjab and Haryana from 1967 to 1978. The GR's main concerns at this point were rice and

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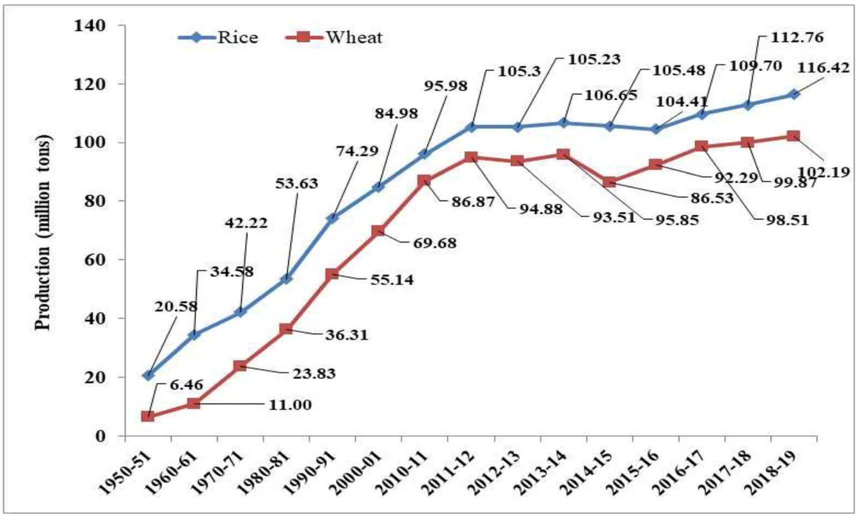

Fig. 1. Production trend of rice and wheat in India from 1950-51 to 2018-19.

wheat. The introduction of high yielding cultivars, increased fertilizer use and enhanced irrigation—the three pillars of GR—led to higher productivity and improved agriculture in India. Even though GR has many benefits in terms of yield, surplus food, it was not a complete success because it only had the best results in the states of Punjab and Haryana. Additionally, new farming techniques result in serious water pollution, reduced genetic diversity, increased pest vulnerability, contaminated soil and environment, water shortages, soil erosion, reduced soil fertility, micronutrient deficiencies and decreased availability. The trend of rice and wheat output in India from 1950 to 2016 is depicted in Fig 1. From 1950 to 2011, there was a nearly five-fold rise in rice production and a fifteen-fold increase in wheat production, but after that the yields remained stable with minimal change (DAC and FW 2020).

Similarly, Fig. 2 illustrates the approximately

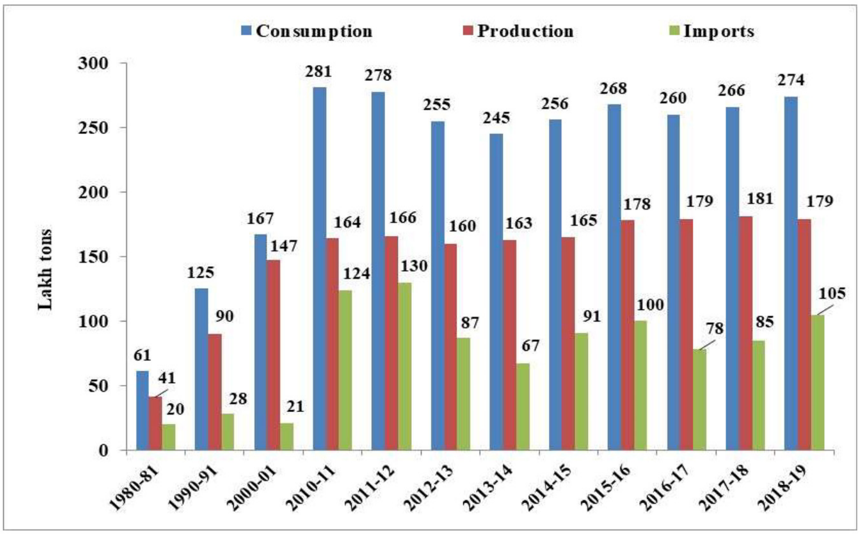

Fig. 2. Trends in consumption, production and imports of fertilizers in India from 1950-51 to 2018-19.

five-fold increase in fertilizer use between 1980 and 2010, which was associated favorably with yields as demonstrated in Fig. 1. However, as a result of a number of factors, including climate change-related heat stress, increased night time temperatures, depletion of soil fertility, salinization, soil erosion, pest and disease build up, cultivars approaching their yield potentials, water scarcity and a lack of funds to purchase more expensive inputs, yield stagnation has since been observed not only in India but also in the rest of the world's cereal-growing nations.

Transition from conventional to organic farming

It is increasingly felt that the modern system of farming is becoming unsustainable as evidenced by declining crop productivities, damage to environment, chemical contaminations. So, the necessity of having an alternative agriculture method which can function in an eco- friendly system while sustaining and increasing the crop productivity is desired. The most well-known alternative to conventional agriculture is organic farming, which has become popular in a variety of soil types and climates. As an alternative, organic agriculture is gaining more recognition and markets for organic foods are growing quickly in many countries, including India (Willer and Yussefi 2005). By utilizing on-farm agronomic, biological and mechanical methods in place of all synthetic off-farm inputs, organic agriculture is defined by the FAO as "a unique production management system that promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity". Indian organic farming is different from conceptions of organic farming around the world in that it is more closely aligned with environmentally sustainable agriculture due to the smaller size of farms, greater use of self-labor, the farmer's more intimate knowledge of field conditions and the lower number of animals managed per household. According to data published by the International Federation on Organic Agriculture Movements, 1.9 million producers in 164 countries are managing 37.5 million ha of land (0.87% of all agricultural land) globally in an organic manner. To drive area expansion and technology transfer, Ministry of Agriculture launched a National Project on Promotion of Organic Farming (NPOF) with funds for setting up of organic including vermicompost and biological input production units and encouraged organic adoption and certification under various schemes such as NPOF, NHM (now MIDH- Mission for Integrated Development of Horticulture), NMSA (National Mission for Sustainable Agriculture) and RKVY (Rashtriya Krishi Vikas Yojana).

Some studies have found that organically managed systems are less productive than conventional systems (Mader *et al*. 2002), while others have indicated that they can be as productive as conventional ones. In order to become a fully certified organic producer, a conventional farmer or grower must go through the process of conversion. The transition period is the "time between the start of the conversion process to when the producer gains full organic certification". Because it takes time for the changes in the soil's chemical, physical and biological qualities to attain an ecological balance, the transitional phase is fraught with difficulties. According to India's National Program for Organic Production, annual crops must go through a minimum 2-year transition period before they can be certified as organically cultivated.

Recommendations for minimizing the transitional problems

Start the conversion process with a leguminous or in a field with a high nutrient status and good soil structure.

Avoid starting the conversion with corn or any crop with a high nitrogen demand.

Permit yields to stabilize over a 2 to 3-year transitioning phase.

Legume green manures should be used in the new rotation.

Gradually reduce the use of external inputs.

Alternate cool season crops with warm season crops to interrupt weed cycles.

Perform field operations in a timely manner.

Changes in the soil physical and bio-chemical

properties of the soil during transition period

During the period of transition from conventional to organic systems after the rapid withdrawal of synthetic fertilizers, insecticides, fungicides and herbicides, yield losses due to nutrient limitation, pest damage and weed pressure frequently happen. In many agricultural soils, nitrogen is one of the primary growth-restricting factors for plants. With the reduction in yield often comes the removal of synthetic fertilizers. Similarly, the absence of pesticides and fungicides during the transition phase may result in pest and/or disease issues. As a result, developing transitional techniques to reduce yield loss is crucial for putting organic farming systems into practice (Mueller *et al*. 2002).

Designing the most effective conversion strategies and reducing yield losses may be aided by having a thorough grasp of the microbial dynamics that take place when conventional to organic systems are switched over. In systems that are organically managed, soil microbes not only supply the majority of the nutrients through mineralization processes, but they can also act as a temporary nutrient sink, building up the nutrient reservoir and lowering the risk of mineral nutrient leaching, especially for N (Friedel *et al*. 2001). The synchronization of nutrient release from organic matter and nutrient requirements for crop growth therefore depends on an active microbial population.

Additionally, soil microbial biomass and activity have been utilized to detect early changes brought on by various soil management strategies because they react quickly to changes brought on by agronomic practices and other disturbances (Doran and Zeiss 2000). Furthermore, soil microbes may prevent plant diseases brought on by pathogens that live in the soil, primarily through antibiosis and competition for resources (Garbeva *et al*. 2004).

In a study conducted by Tu *et al*. (2006), on responses of soil microbial biomass and N availability to transition strategies from conventional to organic farming systems, it was observed that the yields for soybean, sweet potato and wheat were 11–20% lower, while the yield of cabbage was 200% higher in the organic treatment than in the conventional control. At the end of the third year of the experiment, the soil's average total organic C content in the organic plots was 11.2 g C kg^{-1} compared to 8.50 g C kg^{-1} in the conventional control. Although the difference was not statistically significant at $p = 0.05$, the total organic C increased significantly as a result of organic methods. Transitional practices from conventional to organic farming profoundly impacted the size of the soil microbial communities as reported by Tu *et al*. (2006). The mean microbial biomass carbon and microbial biomass nitrogen were highest in the organic plots, with 351 and 55 mg kg^{-1}, respectively, while lowest in the conventional plots with 231 and 34 mg kg^{-1} (Tu *et al*. 2006). Microbial biomass C increased by 9-74% from 2001 to 2002 and was 34% greater at harvest. Soil microbial respiration rate can measure microbial activity. It was significantly enhanced by the organic and reduced input transition practices in both years as compared to the conventional plots.

Gopinath *et al*. (2008) conducted field experiments to study the influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production and found that there were significant differences among treatments with respect to grain yield in both years. These results suggest that the yield gap between the mineral fertilizer and organic amendment treatments narrowed in the second year of transition. The grain yields for all the treatments involving organic amendments were marginally higher in 2nd year of transition than in 1st year, whereas unamended control treatments recorded a slight dip in grain yield in 2nd year compared to 1st year. The results obtained were compared with those in earlier reports (Mader *et al*. 2002, Ryan *et al*. 2004), where organic wheat yields were 17–84% lower than conventional yields. Lower grain yields in the plots amended with organic manures and composts may have been associated with the less readily available nutrients in the initial years of transition as nutrient cycling processes in 1st year organic systems change from inorganic N fertilization to organic amendments (Reider *et al*. 2000). They also reported that the soil bulk density was reduced significantly in all the treatments except mineral fertilized plots compared with the unamended control. To speed up the mineralization process, organic fertilizers should have a C/N ratio of <30:1, since soil microorganisms are essential for maintaining favorable soil conditions (such as soil aggregation, biological control, nutrient cycling, organic matter decomposition and nitrogen fixation), additional factors, such as enzyme activities, should be taken into account (Pfeiffer *et al*. 2013, Hartmann *et al*. 2015, Bender *et al*. 2016). It has been noted that adding organic fertilizers decreases soil phosphorus fixation, allowing plants to absorb more phosphorus (Malik *et al*. 2012). Furthermore, the increase of P availability in organically fertilized soils could be due to high microbial activity induced by the addition of residues which speeded up P cycling (Parham *et al*. 2002). Microbial changes or the small proportion of active microbial biomass during the transition period could explain the lack of correlation between microbial biomass and dehydrogenase activity. Among the different enzymes, phosphatase was earliest indicator of changes occurred in soil due to the organic transition. High input of natural fertilizers not only build up C in soil but also improves other parameters alike pH, bulk density and CEC content (Maharjan *et al*. 2017). However, in transitional time soil nutrient management in organic farming system is still a big challenge.

CONCLUSION

Research-based recommendations must be developed for suitable organic amendments that provide high yields, grain quality and adequate soil fertility during the transition to organic production.

The reduced-input strategies and organic farming practice can rapidly improve soil microbial characteristics, greater enzymatic activity and gradually enhance soil fertility.

During transition period, nitrogen deficiency appeared to be a problem in organic farming.

Among the different parameters studied microbial biomass C, microbial biomass N, total organic carbon and phosphatase was found earliest indicators of changes occurred in soil due to the organic transition.

Composted farmyard manure along with bio-fertilizers can be used for quick stabilization of soil fertility as well as biological activity, which in turn help in nutrient availability and minimum loss in yield during transition period.

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