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RESEARCH ARTICLE

Scope for Adoption of Intercropping System in Organic Agriculture

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ABSTRACT

Intercropping, also known as multi-cropping or poly culture, is an age-old agricultural practice that involves the growing of diversified crop species in close proximity such that they coexist temporally for a portion of their life cycle. Growing of different plant species together enhances biological diversity and thus ensures greater ecological service, which is important in creation of suitable environment for successful organic agriculture. Further, legume crops in association in intercropping system benefit non-legumes by sharing nutrients, enabling soil biological activities and higher use of available resources. The adoption of Green Revolution Technologies (GRTs) resulted in degradation of natural resources with yield decline or stagnation of major crops. During recent time, organic agriculture has emerged as an economically viable option of farming because of growing demand of the organic products worldwide. In addition to that, organic agriculture has enough potential to assure agricultural sustainability. Under these circumstances, intercropping can play a vital role in organic agriculture for sustainable farm output and the article has focused on beneficial aspects of intercropping system in befitting organic agriculture.

Keywords: Green, culture, environment, farm, agriculture, soil.

INTRODUCTION

Agriculture plays a vital role to human society for its existence as it provides food, natural fibre, fuel and some raw materials for industry along with ecosystem services. Agriculture is the most important source of livelihood that shows prominence in economic progress of a developing nation like India. Indian economy is one of the fastest growing economies among the developing world. In India, agriculture supports employment of 54 per cent of the population and still contributes to satisfactory gross domestic product. The agricultural sector in India has made massive pace in the past seven decades. But modern industrialized agriculture is a major source of environmental degradation, contributing to emission of greenhouse gasses and thus causing climate change, reducing freshwater resources, unbecoming soil fertility and contaminating the environment through some man-made practices. These are misuse of natural resources, non-judicious use of chemical inputs for plant nutrition and plant protection and others. Agricultural production system is directly related to the natural resources, which are degrading. Presently, the country produces sufficient food grain, but the modern agriculture flops in attaining the aims of sustainability. The yield plateauing has been observed in the most productive areas of the country where natural resources are over-exploited; pollution due to faulty agricultural practices are prominent and eventually deterioration of natural resources. Sustainability of agricultural production, food and nutritional security necessitates not only that access to sufficient nutritious food to all, but also that the agricultural production system should be lacking any negative ecological effect. In other words, it may be stated that the sustainable agriculture is such a production system that should fulfill the needs of the present without impairing the natural resource and assuring the ability of future generations to meet their needs. That expectation is missing and it is very much clear that modern agriculture will not be able to ful fill the requirements of sustainability.

Cropping Systems in Modern Agriculture

Worldwide cultivable land has been decreased due to increase of global population and industrialization, while global demand for food is increasing. Modern industrial agriculture based on use of huge quantity of chemicals has adverse effect on human and animal health, agro-ecosystem and quality of agricultural products. Furthermore, monoculture has resulted in increased yields, but at the cost of environmental wellbeing. In contrast, sustainable agriculture aims to simulate nature with holistic approach as the pattern for creating agricultural systems by nurturing diversity, integrating plants and animals into a diverse landscape for gratification of the human requirements for today and future. Agricultural production can only be sustained on a long term basis if the land, water and forests on which it is based are not degraded further (Zaman *et al*., 2017). Creation of multiplicity and its effective execution for sustainable agriculture are very important and intercropping suggests simulating nature's principle of diversity on crop lands. Thus, intercropping can be evaluated as pro-ecological approach of raising of crops, supporting above and below ground bio-diversity and compatible crop husbandry with the aims of sustainable agriculture.

A system consists of different components and these are diligently related with a proper interaction among themselves. Emerson (2007) mentioned that cropping system refers to production of crops in sequences or mixture and the management involved in a specific field for a time period. Generally, farmers adopt various cropping systems to maximize farm output, profitability and production sustainability (Hauggaard-Nieson, 2001). The system approach always aims at better utilization of resources and agronomic manipulations and thus assures sustainable productivity as well as enhancement of cropping intensity. The intensive cropping systems focus on maximization of farm output from unit area. The modern concepts of agronomy clearly narrate that the efficiency of a cropping system hangs on the single crop in mono-cropping and / or different crops cultivated in the sequential or intercropping system. Moreover, time and space dimensions are also considered to measure the efficiency of the system more accurately (Willey and Reddy, 1981; Willey *et al*., 1983). However, modern agriculture resulted in mechanization, monoculture, cultivation of improved varieties and hybrids of crops, use of chemical fertilizers and nutrients led to a simplification of the interacting components in agricultural systems and ultimately caused genetic erosion, greater susceptibility to abiotic stress and thus vulnerability in cropping system. Restoration of biodiversity through growing of different crops and adoption of farming systems that result in the efficient exploitation of available resources is important for sustaining farm output (Jackson *et al*., 2007; Scherr and McNeely, 2008). The modern agriculture has assured enhancement in production and productivity, but simultaneously brought uncertainty in farming with a threat to agricultural sustainability (Tilman *et al*., 2002; Lichtfouse *et al.,* 2009). No sooner had India embraced the Green Revolution in 1960s, than it realized its adverse effects a decade later.
The Green Revolution was characterized by mainly research development and initiatives for transfer of technology and no doubt these enhanced agricultural productions worldwide, particularly in the developing countries (Maitra *et*

al., 2018). The production enhancement noted was mainly due to arrangement of assured irrigation, use of huge quantity of chemical fertilizers and cultivation of ideo types and high yielding varieties of crops. During that period, monocropping became the economically effective path to move. Soon fertilizer shortages and increasing prices developed, which created another problem including lowering of profit. As synthetic fertilizer is a fossil fuel based product, agriculture was gradually becoming dependent on crude oil extraction. Also, environmental complications associated with non-judicious use of fertilizers and other agro-chemicals were becoming prominent. These resulted in surface and groundwater pollution, degradation of soil and ultimately created an unbalance on crop-ecology (Joseph *et al.*, 2018). Monoculture is characterized by devoid of diversity and increases pest, disease and weed problem. The plant protection became difficult because of insufficient population of pest predators (Horrigan *et al*., 2002), which further encouraged use of more plant protection chemicals. As these and other problems associated with the monoculture system became more apparent, interest in intercropping grew as possibly, part of the solution to achieving and maintaining sustainability (Manasa *et al.,* 2018). Intercropping is one of the many systems that hold great potential in solving future food and economic problems in developing countries. The main reason for the acceptance of intercropping for smallholders is that it has greater stability than monocropping. Due to different aberrant environmental conditions there may be a chance of crop failure is common in fragile ecologies of the developing countries and intercropping ensures stability as it ensures partial restoration of species diversity and improvement of soil fertility (Li *et al.*, 2001; Gitari *et al*., 2018; Gitari *et al*., 2020; Manasa *et al*., 2020), which are not common in monocropping.

Intercropping

A Felt-need

For achieving sustainable agricultural productivity, the researchers of the developing countries always focus on low-input and energy-efficient agricultural systems (Maitra *et al*., 2019) and intercropping is considered as a choice. Besides, diversity in agricultural system can be further enriched temporally by crop diversification or spatially by adoption of intercropping systems (Altieri, 1999). Maintenance of on-farm diversity is very much common in many countries and mostly in developing world, where traditional farming systems are observed with cultivation of different crops together in the form of mixed and intercropping (Maitra *et al*., 2019; Maitra 2020). In an intercropping system, two or more crops may be sown or harvested at the same or different time, but they are grown together for a major portion of their growth periods and the main crop gets more importance for economic gain (Maitra *et al*., 2001) and additional crop provides support to enhancement of productivity and income. The sequential cropping is no doubt important for increasing the intensity of cropping, but intercropping system benefits a lot by enhancing farm output, monetary advantage and efficient utilization of available resources.

Organic Agriculture: A Way Forward

To accomplish and address social, ecological and economic concerns together, organic agriculture can play a dynamic role. Organic agriculture has a long tradition and heritage in India that progressed over the millennium. Organic agricultural is a complete production system, which improves ago-ecosystem health, inclusive of biodiversity, biological cycles, and soil biological activity. It emphasizes the use of mostly on-farm inputs considering the regional conditions with locally adapted closed farming system. As proposed by International Federation on organic agriculture movement (IFOAM), there are four principles of organic farming (Figure 1), which may be considered as pillars (IFOAM-Organics International, 2018). India has numerous kinds of available organic form of nutrients in different locations of the country, which can be used for supplying nutrients to plants. India initiated the National Program for Organic Production (NPOP) by Agricultural and Processed Food Products Export Development Authority (APEDA) in 2001. The organic production standards prepared by NPOP have been created under guidelines of international organic production standards such as CODEX Alimentarius [United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO)] and IFOAM. The standards followed by NPOP for organic agriculture production and accreditation system have been accepted by European commission, US and Switzerland as it follows the world class norms. In traditional agriculture in India, the agriculture production system was fully dependent on organic inputs obtained from fresh or decomposed plant and animal products. The traditional farming system is regarded as production of food and other agricultural products by small and marginal farmers producing for their families and local consumption. During post green revolution era, Indian agriculture system has been changed with introduction of chemical inputs. No doubt, there was enhancement in grain production, but it was achieved at a cost of environmental issues and agriculture in India ultimately has lost its sustainability. Presently, for achieving sustainability, once again agriculturists are opting for organic agriculture. Production of additional food from the same land area without degrading the ecology requires sustainable intensification (Royal Society of London, 2009). By adoption of some agronomic management ill effects on environment can be reduced targeting agricultural sustainability and organic agriculture has enough potential. Organic agriculture is a unique production management system which mostly disregards the usage of artificial inputs (like chemical fertilizers, pesticides, synthetic hormones, food additives and so on) and it rely upon crop rotations and crop diversification, use of crop residues and animal manures, organic wastes, mineral grade rock additives and biological system of nutrient mobilization and non-chemical inputs for plant protection.

However, organic agriculture is not only replacing use of inputs but it is more a farming system approach for creation of a healthy agro-ecosystem targeting the achievement of the four principles of organic farming as advocated by IFOAM. In broad sense we can say organic agriculture is actually a farming system targeted with minimal harm to agro-ecosystems, animals or humans (FAO and WHO, 2007). During recent times, awareness of health and environmental issues in agriculture has been increased which necessitated production of organic food. Organic agriculture is a cost effective and sustainable choice of farming, particularly by the smallholders of rain fed and dryland areas and supports to boost their food and income security. It helps to produce and supply adequate safe and nutritious food to the producers and consumers. Environmental advantages, health benefits and strengthening of farmers' economy are other key factors influencing farmers to shift to organic agriculture.

Organic Agriculture and Intercropping

The success of organic agriculture is lying on some cultural practices of which system approach, crop diversification, inclusion of legumes in cropping system, restoration of soil fertility and reduction in degradation of natural resources and stability in production are important. These basic requirements can be achieved by adoption of intercropping systems. On-farm bio diversity can lead to healthy agro-ecosystems accomplished of maintaining soil fertility and sustaining productivity (Scherr and McNeely, 2008) and intercropping system can create diversity. Crop diversification happens in intercropping system, because two or more crops are cultivated together in the same field. In addition, cultivation of at least two crops of preferably dissimilar type under intercropping creates above ground diversity by attracting pollinator and predators (Maitra and Ray, 2019). The intercropping systems encourages the population of bee and other insect pollinators (Nicholls and Altieri, 2013), which ultimately enhances yield.

Legumes are known to host predators, which can manage pest population dynamics and thus pest management becomes easier (Maitra and Ray, 2019). In organic agriculture, weeds are managed by cultural, mechanical and biological methods. Intercropping system assures less population and growth of weeds because crops cover more ground area suppressing weed growth. Not only the above ground diversity, but also beneficial soil micro-organisms are enriched in cereal-legume intercropping system. Moreover, application of organic manure in soil facilitates suitable environment for increasing the numbers of beneficial micro-organisms. Intercropping cereals with legumes assures presence of soil micro-organisms, namely, *Alphaproteobacteria, Betaproteobacteria* and *Cyanobacteria* (Qiao *et al.,* 2012; Li and Wu, 2018). Rhizobium colonizes in legumes roots and it has been observed that in Rhizobium rich soils, other beneficial microorganisms harbor in rhizosphere and thus soil is enriched biologically favouring crop growth and sustainable yield. Besides, some other free-living soil bacteria like *Pseudomonas denitrificans*, *P. rathonis*, *Bacillus laevolacticus*, *B. amyloliquefaciens* and *Arthrobacter simplex* are observed to enhance plant growth in intercropping. *Rhizobium* species is also beneficial in reduction of harmful pathogens like *Fusarium*spp. and *Phytophthora* spp. (Maitra and Ray, 2019). Thus diversity creates a healthy ecosystem services and sustainability in crop production. In crop-livestock farming system, for nutrient management in organic agriculture wastes of livestock and crops as well as manures are used. But in livestock-free system, legumes contribute a lot in organic production. Legumes can fix nitrogen biologically from atmosphere and play a vital role in the N-economy of the system (Amosse´ *et al*., 2013). In an experiment on soybean-maize intercropping system, ^{15}N labeling showed that *Glomusmosseae* and *Rhizobium* SH212 inoculation increased the N transfer from soybean to maize (Senaratne *et al*., 1995). The fixed N is transferred to non-legume component through root excretion, root and nodule senescence, leaching of N from leaves and leaf fall (Fujita *et al*., 1992; Ledgard and Giller, 1995). The amount of N fixed biologically and transferred to other non-legume component depends on some factors like legume species, morphology, duration and management practices adopted (Nasar *et al.,* 2020). The short duration green gram (*Vigna radiata* L.) fixes N than long duration red gram (*Cajanas cajan* L.). Moreover, a portion of biologically fixed N is utilized by the succeeding crops, depending upon the quantity of N fixed and utilized (Sarath Kumar and Maitra, 2020). Phosphorus, Fe and Zn nutrition of cereals and/or legumes can be improved by adoption of intercropping through the increased availability of these nutrients in the rhizosphere (Xue *et al*., 2016). Relay intercropping system of legumes with cereals is beneficial for enrichment of the soil–plant system in N through symbiotic fixation (Amosse´ *et al*., 2013).

In Intercropping system, more biomass yield is obtained and crops utilize greater quantity of CO_2 and thus atmospheric pollution is reduced to some extent. Further, renewable solar energy is more utilized by crop mixture for biomass production. Combination of shallow and deep rooted crops are often chosen in intercropping system leading to efficient utilization of soil nutrients by crops from different layers. Maize-legume relay strip intercropping system can minimize soil moisture evaporation than pure stands and under limited water conditions maize-soybean combination is beneficial for maximizing water use efficiency and more yields (Rahman *et al*., 2017). Combination of shallow and deep rooted crop is advantageous in intercropping not only for utilizing better use of nutrients, but efficient use of soil moisture. Experimental results indicated that finger millet may be benefited by deep rooted pigeon pea by bio-irrigation when biofertilizer inoculation was done with arbuscular mycorrhizal fungi (AMF) and plant growth-promoting rhizo bacteria (PGPR) under dry land conditions (Saharan *et al*., 2018).

Further, more ground cover in mixed cropping ensures less run-off of water, soil erosion and less nutrient loss from the soil (Dass and Sudhishir, 2010;Gitari *et al*., 2019). The positive effects of intercropping system are also noted in resource conservation and soil health management as it checks run-off of water, soil erosion and less nutrient loss from the soil (Nyawade *et al*., 2019). The intercropping combination of finger millet + black gram recorded the lowest runoff (10.2%) and losses of soil and nitrogen, phosphorus and potassium through erosion over sole when sown in contour because black gram covered enough ground area in intercropping with finger millet. The soil fertility status was also improved in finger millet + pulses intercropping, which was due to contribution of leaf fall and biological nitrogen fixation by legumes. Comparatively low soil and nutrient losses from intercropping systems and legume effect contributed to increased nutrient status under finger millet and legumes intercropping (Dass and Sudhishir, 2010). Further, legumes can be a good resource of energy and these can be digested in the bio-gas chamber from which renewable energy can be generated and slurry can be used as nutrient resource. Chemical N fertilizer production system is involved with fossil fuel consumption and emission of greenhouse gases. However, legume–cereal intercrop mixture can assure energy saving and emission saving process with no adverse impact on environment. The enrichment of biodiversity and soil health improvement is possible in intercropping and these enable greater ecosystem services. Thus intercropping system preferably legume as a component may be considered in organic agriculture for multiple benefits targeting production sustainability**.**

CONCLUSION

Considering the growing demand of organic agriculture, farmers of the developing countries are showing interest in chemical-free agriculture targeting domestic as well as export market. Input management in organic agriculture is also costly because of bulky nature of organic nutrients with low analytical value. Organic agriculture basically relies on system approach and there is enough potential of intercropping system in terms of nutrient management, greater resource use, management of pest population dynamics and higher ecosystem services. The present article concludes that intercropping system should be an integral part of organic agriculture assuring sustainability.

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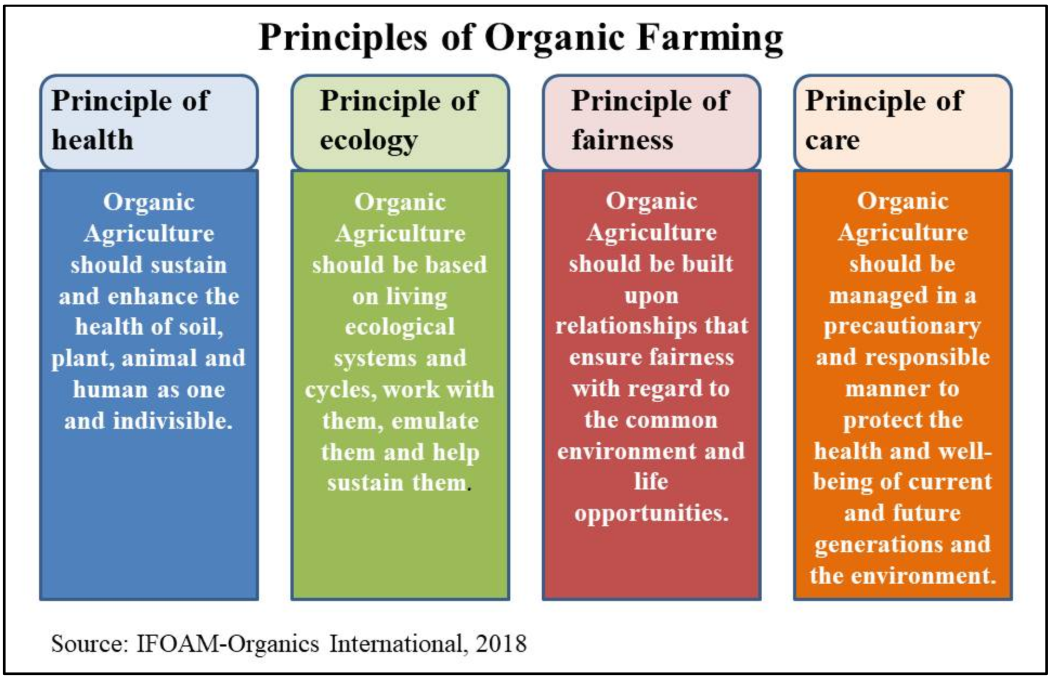

Fig. 1. Principles of Organic Farming