Intercropping

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Intercropping ensures multiple benefits like enhancement of yield, environmental security, production sustainability and greater ecosystem services. In intercropping, two or more crop species are grown concurrently such that they coexist for a significant part of the crop cycle and interact among themselves and with agro-ecosystems.

food environment intercropping security sustainability

1. Introduction

Agriculture plays a significant role in most of the developing countries. But due to the increased population and development of urban clusters along with industrial growth in the developing world, there is shrinkage in the availability of land for farming because of its non-agricultural uses. Under these circumstances, the adoption of high-intensity cropping systems may be the viable option to increase agricultural productivity and production as a whole[1][2]. Agriculture is a tradition and heritage in most countries. Traditional farming practices are evidenced around the world with the growing of crop mixtures which is nothing but a form of mixed cropping or intercropping. The farming systems of ancient periods in different corners on the planet are documented as having grown crop mixtures which were nurtured by the people for a long time[3]. Early civilizations evidenced the use of intercropping that might be in a different form. South Asian subcontinent experienced growing of diversified crops with environmental diversity[4][5][6] since the Indus Civilization (c. 2600–1900 BC) in the form of mixed cropping or multi-cropping or intercropping[7][8]. Furthermore, the intercropping system was well known in Greece since about 300 B.C. which indicated growing of cereals and pulses[9] in which pulses were planted at different times during the growing season of cereals like wheat and barley[10]. Traditional mixed cropping has enough potential to contribute as much as 15–20% in the food basket of the world[11]. In Latin America, maize-based intercropping is very common[12]. In Africa, 89% of cowpeas and in Colombia 90% of beans are growing in mixed stands; however, in Malwai intercropping is very common and occupies 94% of cultivated land[13].

Various types of intercropping were known and presumably employed in ancient Greece about 300 B.C. Theophrastus, among the greatest early Greek philosophers and natural scientists, noted that wheat, barley, and certain pulses could be planted at various times during the growing season often integrated with vines and olives, indicating knowledge of the use of intercropping[9]. In tropical countries, intercropping is generally observed with food crop production, but much emphasis has been given in forage production in the temperate world for fulfilment of the high demand for animal feed[14].

Intensive mono-cropping is less complicated for big-scale farmers with the fullest utilization of machines, while smallholder farmers do not have steady access to markets and only produce enough food for their family members under subsistence farming. Intercropping ensures their livelihood. Therefore, intercropping is mainly practiced on small farms. Moreover, intercropping is known to produce stable yields from diversified crops with less use of inputs for nutrient supply and plant protection, focusing on sufficient food under healthy environmental conditions. In organic agriculture, intercropping is useful because less incidence of pest, disease and weed occurs and soil fertility is maintained[15]. During the recent period, the system approach in agriculture has drawn more attention from researchers. A system is comprised of different constituents that are high with interaction among them. The system approach targets greater use of available resources resulting in production sustainability and enhancement of intensity. The cropping systems with a more intense focus on raising of crops and varieties or hybrids having tolerance to biotic and abiotic stresses, capacity to replenish soil for sustainable production and express higher yield. Developing suitable cropping systems is an enormous job for achieving potential yield under any agro-climatic conditions[16]. Actually, some factors like resource availability and management are mainly considered to evolve a cropping system. The competence of a cropping system rests on the productivity of crops, time duration and requirement of land[17][18].

Modern agriculture based on supply with high energy and fossil-fuel-based inputs that are commonly known as Green Revolution Technologies has resulted in a remarkable enhancement in crop yields, but once this flourish was achieved agricultural sustainability disappeared[19]. The modern farming systems infer monoculture, replacing biodiversity with few crops and a limited number of cultivars in vast areas. On the other hand, on-farm biological diversity is maintained by the traditional farmers of developing nations and mixed cropping, intercropping and agroforestry patterns are prominently observed. These farming systems offer the ability to grow a variety of crops, assured production, efficient use of resources, less chance of crop damage by pests and diseases and proper use of the human workforce with a standard income[14]. Different crops grown in an intercropping system may or may not be seeded or harvested simultaneously, however, the crops remain in the same field for a major part of the crop periods. There are various types of plant species that can be included in intercropping, namely, annual crops like cereals, legumes, oilseeds, fodder crops and so on. Low-input and energy-efficient crop production systems are no doubt attractive for sustaining agricultural productivity[11][22], but, modern agriculture imposed less diversified crop production system with the use of high energy inputs and chemicals. Agricultural sustainability can be achieved by creating on-farm diversity and proper use of natural resources with greater ecosystem services[21][22]. Biological diversity in a crop-growing environment can be improved by a recurrent succession of crops in sequential cropping or intercropping systems[11]. Actually, modern agriculture increased crop yields but developed issues related to agricultural sustainability[23]. An intercropping system has enough potential to enable sustainability in agriculture by crop diversification, efficient resource management and soil fertility restoration. The review focuses on essential aspects of intercropping systems as low-input management practices for food and environmental security with agricultural sustainability.

2. Intercropping as Low-Input Agriculture

An economically viable agriculture production system demands a supply of sufficient quantity of inputs. The success of green revolution (GR) in the second half of the previous century greatly focused on the supply of essential inputs and so green revolution technologies (GRTs) were more commonly known as supply-driven technologies. As per the concepts of GRTs, important inputs used in agriculture are high-yielding varieties (HYVs), fossil fuel-based high-energy chemical fertilizers, assured irrigation, use of sufficient plant protection chemicals and so on and interestingly all these inputs need high energy. On the other hand, intercropping systems need comparatively fewer energy inputs like fertilizer, plant protection chemical requirements are less, and diversification of crops is greater creating functional diversity resulting in less pest-disease incidence. Moreover, there is the creation of soothing microclimate with less evaporation[24][25]. Combination of deep-rooted and shallow-rooted crops create the options of bio-irrigation and after all, legume crops in association with non-legumes favour adjustments of nutrients by benefitting non-legumes in the form of nitrogen fixation. The legumes, furthermore, create a congenial environment for harbouring different beneficial microorganisms favouring higher ecosystem services. The cumulative impacts of all factors are reflected in the intercropping system and thus the intercropping system can be considered as a low input agriculture practice with higher output in terms of higher farm output and agricultural sustainability.

3. Concept and Goal of Intercropping

Cultivation of two or more crop species concurrently as they coexist for a significant part of the crop cycle is known as intercropping and it is also sometimes termed as polyculture or mixed cropping[14]. The component crops are neither seeded at the same time nor harvested, but they remain simultaneously in the field for a major portion of the growth periods of component crops. Intercropping is, in general, comprised of the main crop and one or more companion crops, where the production of the main crop is the prime goal. Intercropping is actually the value addition of the cropping system which can ensure higher productivity, efficient use of resources, and more income[26][27][28].

The history of the adoption of intercropping is not known, but ancient civilizations witnessed cultivation of crop mixture. Intercropping is still adopted in developing countries and it is also observed that intercropping began disappearing from many areas with the advent of high energy-based modern agriculture. The shift from polyculture to so-called ‘modern monoculture’ was driven primarily by commercialization and specialization of industrial agriculture along with the involvement of chemical-based inputs and assured irrigation. Increasing interests in sustainable crop production and ecological issues have distracted consideration back to polyculture as a path of efficient use of available resources with as much care as possible for ecology and leading towards agricultural sustainability. Since the historical period, intercropping activities were noted in different countries of the world with various crop mixtures with cereal mixtures found commonly in temperate regions[12]. Nonetheless, intercropping gained importance and is widely practiced in tropical regions because of extensive genetic diversity in terms of crop choice as well as cropping systems[29][30][31]. Furthermore, the decline in temperature and rainfall is inversely proportional to adoption in a variety of intercropping systems[32]. With the adoption of industrialized farming, intercropping started to disappear from different parts of developed and industrialized countries as monoculture

became popular there. This drift was motivated by the use of high energy inputs, improved farm machinery and specialization and these were considered as the prime strategy for enhancing crop yield. This industrialized agriculture was successful with a single crop or commodity, but the question of higher system products, as well as agricultural sustainability, remained unanswered over time[33].

In intercropping, basic ecological principles are observed in the form of above and belowground diversity, competition, and facilitation, for production of crops[34]. Generally, if the polyculture system of crops is chosen with proper prerequisites, the yield output appears higher than pure stands of individual crops. Moreover, in the intercropping system, different resources are better used by crops from a common pool compared to pure stands of the respective crops which result in greater productivity[34][35]. An intercropping system assures more coverage of the ground area by the canopy of crops, more transpiration takes place by the foliage which may create a cooler microclimate, and this facilitates the ability to minimize the soil temperature[36]. Under moisture stress conditions, in intercropping systems, crops use available water in the form of soil moisture and this microclimate provides a soothing effect at the canopy level of crops[37]. Generally, in intercropping, morphologically dissimilar crops are chosen with different growth habits, so available resources are efficiently utilized and the ultimate gain is the conversion into the crop dry-matter production or crop yield[10]. Different factors like choice of crops and cultivars, sown proportions and agronomic management including water and nutrients and the competitive ability of crops can affect the performance as well as the success of intercropping systems.

4. Types of Intercropping

Intercropping is the raising of two or more crops together as they coexist for some time on the same land. The spatial and temporal crop intensification is done in intercropping and it may be of different combinations of annual and perennial crops as per the choice of the farmers and suitability to the growing conditions[38]. Furthermore, in intercropping, competition is noted among the component species grown during the entire crop period or a part of growing duration for available resources. Different types of intercropping systems are adopted in various countries which can be grouped into the following[39].

4.1. Row Intercropping

The row intercropping is raising of one or more crops sown in regular rows, and growing intercrops in a row or without row at the same time. The row intercropping is a usual practice targeting maximum and judicious use of resources and optimization of productivity[39].

4.2. Mixed Intercropping

In mixed intercropping, two or more crops are grown together without any definite row proportion. Sometimes it is also referred to as mixed cropping[41]. In pasture-based cropping system, grass-legume intercropping is an ideal example of mixed intercropping[42]. The mixed intercropping is commonly observed to fulfil the requirement of food and forage where the land resource is a limiting factor[43]. Furthermore, a review work clearly described perennial

polycultures as an agroecological strategy in cropping system with enough potential for the sustainable intensification of agricultural systems spatially and temporally[44].

4.3. Strip-Intercropping

The strip-intercropping is a type of intercropping where two or more crops are cultivated together in strips on sloppy lands. Strip intercropping is known to enhance greater radiation use efficiency in marginal and poor lands[45]. A combination of soil conserving and depleting crops are taken in alternate strips running perpendicular to the slope of the land or the direction of prevailing winds. An important objective of strip cropping is the reduction of soil erosion and harvesting of yield output from poor lands.

4.4. Relay Intercropping

Relay intercropping is raising two or more crops at a time during a portion of the growing period of each. In this system, the second crop is seeded when the first crop completes a major part of its life cycle and reaches reproductive stage or close to maturity but before harvest. The areas with limitation of time and soil moisture are more appropriate for relay cropping[46]. Before harvesting of the preceding crop, the next crop is sown and both the crops remain in the field for some period of their cycle. However, the succeeding crop yields less compared to normal sowing in sequential cropping and more seeds of the succeeding crop are required to obtain a good stand.

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