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AGRONOMY

Potential of Intercropping System in Sustaining Crop Productivity

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ABSTRACT

Intercropping, an age old agricultural practice of cultivating two or more crops in the same space at the same time is generally adopted for more production by utilizing available growth resources. Choice of crops is very important to reap a better harvest from intercropping. The selection of a suitable intercropping system is sort of complicated issue as the success of intercropping depends much on the interactions between the component crop species, proper management practices and favorable environmental conditions. Intercropping has a huge potential and multiple advantages. The advantages are like efficient utilization of resources, enhancement of soil fertility by including legumes as component in mixture and soil conservation through covering the greater ground cover. Moreover, intercropping reduces attack of insect pest, checks the incidence of diseases and restricts weed population and thus minimizes the use of protection plant chemicals. This article addresses an overall view with a focus on prime advantages supported by evidences from the literature based on earlier research.

Highlights

- Types and advantages of intercropping
- Crop choice in intercropping

Keywords: Cropping system, intercropping, crop productivity, sustainability

The greatest challenge of the present time in the agriculture front in a populous country like India is to produce more of farm products namely food, fodder, fuel and fiber for increasing human and animal needs from the limited available arable land. The availability of land for agriculture is shrinking every day due to pressure in utilization for non-agricultural purposes. Under this situation, one of the important strategies to increase agricultural output is development of high intensity sequential cropping and intercropping systems. In the recent years the system approach has gained importance in agriculture. A system consists of several components which are closely related and interacting themselves. The system approach always aims better utilization of resources and thus assures sustainable productivity with enhancement of intensity. The intensive cropping systems must be focus on biotic and abiotic stress resistance of crops and varieties or hybrids, soil building capability of chosen species and more yielding from unit area. Evolving of suitable cropping systems based on agro-climatic conditions and available resources is a huge task for realizing the potential production and the outcome of a cropping system is measured by the efficiency of the component crops by utilization of resources efficiently. As per the modern concepts of agronomy, the efficiency of a cropping system depends not only on the individual and / or component crops of the system, but also another two dimensions namely, time and space (Willey and Reddy, 1981; Willey *et al.* 1983).

Low-input and energy-efficient agricultural systems are in the centre of attention of researchers and policy-makers in the world for sustaining agricultural productivity (Altieri *et al.* 1983; Altieri 1999). However, most of the practices of modern agriculture, like mechanization, monocultures, rely on only few improved crop varieties and hybrids, heavy use of agrochemicals for nutrient and pest management, led to a simplification of the components of agricultural systems, their interaction and caused genetic erosion. Restoration of biodiversity through diversification and adoption of farming systems that mimic efficient utilization of natural resources is considered to be a key for sustaining agricultural productivity (Jackson *et al.* 2007; Scherr and McNeely 2008). Biodiversity in agro-ecosystems can be enhanced in time through adoption of proper crop rotations and cropping sequences or intercropping systems in space (Altieri 1999). But modern agriculture has brought enormous enhancement in productivity to feed the world, but at the cost of sustainability (Tilman *et al.* 2002; Lichtfouse *et al.* 2009). India witnessed Green Revolution and its adverse effects. By contrast, maintenance of on-farm biodiversity and indigenous technical knowledge in farming is familiar to traditional farmers in many developing countries, where traditional farming systems are prominent by their great degree of genetic diversity in the form of mixed cropping and intercropping (Altieri 1999). Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time and sometimes referred as mixed cropping or polyculture (Andrews and Kassam, 1976; Ofori and Stern, 1987; Anil *et al.* 1998). The component crops of an intercropping system neither necessarily has to be sown at the same time nor they have to be harvested at the same time, but they are grown simultaneously for a great part of their growth periods. In intercropping, there is normally one main crop and one or more added crops, with the main crop being of primary importance for economic importance. The two or more crops of preferably dissimilar types are grown in an intercropping system. There is no doubt that sequential cropping is important for enhancement of cropping intensity, but intercropping adds value in cropping system by many ways like assuring more output, better utilization of resources and monetary advantage (Maitra *et al.* 1999; Maitra *et al.* 2000; Manasa *et al.* 2018).

INTERCROPPING AND ITS TYPES

Intercropping is the growing of two or more preferably dissimilar crops simultaneously on the same field. Crop intensification is done in terms of both space and time. Intercropping may be of annual crop with annual intercrop; annual crops with perennial intercrops; and perennial crops with perennial intercrops (Eskandari *et al.* 2009). There is intercrop competition during entire or part of growth period of the component crops.

Based on the per cent of plant population or proportion of crops used in intercropping system, it is divided in to two categories, namely, additive series and replacement series. In additive series, one crop is sown with 100 per cent of its recommended population in pure stand, which is known as the base crops. Another crop known as intercrop is introduced into the base crop by adjusting row spacing or changing planting geometry. The population of intercrop is less than its recommended population in pure stand. The land equivalent ratio (LER) of additive series remains always greater than unity. Additive series is the most efficient intercropping system and commonly adopted in India. However, in replacement series both of the crops are called component crops. By scarifying certain proportion of population of one crop component, another component is introduced.

Further, different types of intercropping are practiced worldwide and can be divided into following four types (Ofori and Stern 1987).

1. Row intercropping

Growing two or more crops simultaneously where one or more crops are planted in regular rows, and crop or other crops may be grown simultaneously in row or randomly with the first crop.

2. Mixed intercropping

Growing two or more crops simultaneously with no distinct row arrangement is known as mixed intercropping and sometimes it is considered as mixed cropping. This type of can be suitable for grass-legume intercropping in pasture based system.

3. Strip-intercropping

Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically.

4. Relay intercropping

Growing two or more crops simultaneously during part of the life cycle of each is termed as relay intercropping. The second crop is planted when the first crop has reaches to its reproductive stage or close to maturity but before it is ready for harvest.

CROP CHOICE IN INTERCROPPING

The success of intercropping greatly depends on choice of component crops of a mixture, taking into account the crop environment of a locality and the varietal availability. The perfect crop combinations and their complementary and synergistic effect if reflected in intercropping, yield benefits are noticed. Maitra *et al.* (2000) observed that intercropping of finger millet + pigeon pea and finger millet + groundnut registered higher net return and benefit: cost ratio than combination of finger millet with green gram and soybean with same row proportion when the experiment was conducted in red and lateritic belt of West Bengal, India. Fan *et al.* (2006) recorded more biomass production and grain yield of faba bean when intercropped with maize; however yield of fava bean was recorded less when it was intercropped with wheat. In intercropping, generally, a deep rooted crop is sown with a shallow-rooted crop (like finger millet + green gram) or planting a tall crop with a short crop (like maize + groundnut) for better management of resource. Maize seems to dominate as one of the cereal components of intercrops, often combined with legumes crops and studies showed better utilization of resources (Manasa *et al.* 2018). The combination of cereals + legumes in intercropping offers a scope for developing energy-efficient and sustainable system as the legumes have the N-fixing capability and more protein yielding potential in the form of either grain or forage.

There are many crop species which can be chosen in intercropping: annuals (cereals and legumes), perennials including trees, or a mixture of the both. In the latter case the term that is used mostly is agroforestry or alley cropping. Besides, crop morphology and the duration of component crops in combinations are also considered while choosing a suitable intercropping system.

ADVANTAGES OF INTERCROPPING

Intercropping is one of the possible ways to increase diversity in an agricultural ecosystem. Intercropping can assure ecological balance, more utilization of resources, enhancement of crop productivity and thus sustainability in agricultural production. There are many reports concerning the positive effects and also superiority of intercropping than the pure cropping. The advantages of intercropping are mentioned below.

Yield advantage

The main reason for adoption of intercropping is to produce higher yield than a pure stand of same land area in a given period (Caballero and Goicoechea 1995). Wiley (1990) considered intercropping as an economic method for higher production with lower levels of external inputs. This increasing use efficiency is important, especially for small-scale farmers and also in areas where growing season is short (Altieri, 1995) and in rainfed areas (Maitra *et al.* 2001a; Maitra *et al.* 2001b). Production more in intercropping can be attributed to the higher growth rate, more biomass production and efficient use of space and resources (Willey 1990; Willey 1985). Moreover, in any intercropping system if there are complementary effects among the component crops, production increases due to less competition among crops (Willey 1979). Yield advantage is noted both in additive (Manasa *et al.* 2018) and replacement series (Maitra *et al.* 2000; Maitra *et al.* 2001b). An alternative to yield for assessing the advantages of intercropping is to use units such as monetary units or nutritional values which may be equally applied to component crops (Willey 1985).

Greater use of resources

Intercropping assures more efficient utilization of the resources and higher productivity compared with each sole crop of the mixture (Willey, 1979; Maitra *et al.* 2000; Andersen *et al.* 2007; Mucheru - Muna *et al.* 2010). Yield advantage pronounces due to growth resources such as light, water, and nutrients are better utilized, absorbed and converted into biomass by the intercrop over time and space .But there may be expression of competitive ability for growth resources between the component crops. Ghanbari *et al.* (2010) worked on intercropping maize with cowpea and reported that there was increased light interception in the intercrops with reduced water evaporation and thus improved conservation of the soil moisture compared with maize alone. The yield advantage is noted when the component crops in an intercropping system do not compete for the same ecological niches and the inter-specific competition for a given resource is weaker than the intraspecific competition. The biggest complementary effects and biggest yield advantages occur when the component crops have different growing periods so make their major demands on resources at different times (Ofori and Stern 1987). Therefore, crops with different maturity express the maximum demand for nutrients and moisture, aerial space and light could be suitably intercropped (Enyi 1977). For instance, Reddy and Reddi (2007) stated that, in maize-green gram intercropping system, peak light demand for maize was around 60 days after planting, while green gram reached to its maturity stage. Thus, selection of crops that differ in competitive ability in time or space is essential for an efficient intercropping system along with seeding time, density and geometry. Francis and Decoteau, (1993) reported that sweet corn yield increase by planted with pea as intercrop due to better use of environmental resources.

The success of intercropping systems and performance of component crops are governed mainly by the availability of and the competition between the components for the environmental resources. Earlier studies clearly indicated that intercrops showed better performance when component crops differed in growth duration (Smith and Francis 1986). Actually, land equivalent ratio (LER) shows the efficiency of intercropping for using the natural resources compared to pure stand and the LER is greater than unity clearly exhibits the superiority of intercropping (Willey 1979; Willey and Rao 1980). Rao and Willey (1980) recorded the highest LER when long duration pigeon pea intercropped with short duration *Setaria*, however, the lowest LER was noted with pigeon pea and slow-maturing sorghum. By contrast, the component crops having similar growth durations show their peak requirements for growth resources almost at the same time and compete for the same. The area time equivalent ratio (ATER) as suggested by Hiebsch (1978) can also be considered to measure the efficiency of the intercropping system where land area as well as time both is considered. However, the LER generally overestimates and ATER underestimates the land use efficiency. In an experiment, Maitra *et al.* (2000) studied finger millet-legume intercropping system in replacement series and noted greater value of ATER with the combination of finger millet and red gram (4:1) than other combinations like green gram, groundnut and soybean with same row proportions. Moreover, in the experiment LER was also noted with the combination of finger millet and red gram.

Reduction of pest, disease and weed problem

Intercropping systems can influence the presence of insect pests, diseases and weeds. Crops grown in intercropping system enhance the population of beneficial insects like predators and parasites, which ultimately check the build-up of pest population dynamics. In this way cost involvement in plant protection is reduced, use of poisonous chemicals is minimized which ultimately checks pollution to agro-ecosystem. The addition of more than one species in intercropping can simply affect the host and habitat complexity of insects. Changes in environment and host plant quality lead to direct effects on the host plant searching behaviour of insects as well as their developmental rates and again interactions with natural enemies adds further dimension. In a review by Francis (1976) on intercropping showed that in 53 per cent of the experiments intercropping reduced the pest population. Kyamanywa and Ampofo (1988) reported reduction of pest incidence in intercropping of beans, cowpea and maize and increased populations of natural enemies. Intercropping cowpea with cotton showed the best performance in suppressing the attack of thrips and whiteflies and recorded high yield (Chikte *et al.* 2008). Intercropping upland rice with groundnut was superior to monoculture of rice in terms pest management as the population of green stink bug (*Nezara viridula*) and stem borer (*Chilo zacconius*) infestations in rice compared were low (Epidi *et al.* 2008).

Intercropping was observed as an effective tool against management of plant diseases. In intercropping, crops are grown in mixture which provides functional diversity that restricts expansion of pathogen due to differential adaptation due to presence of diversified pathotypes (Finckh *et al.* 2000). Some of the examples can be presented from earlier studies. Intercropping potato with maize or haricot beans has been reported to reduce the incidence and the rate of bacterial wilt (*Pseudomonas solanacearum*) spread in potato (Autrique and Potts, 1987). Angular leaf spot (*Phaeoisariopsis griseola*) is a very common disease to climbing genotypes of common beans and less diseased pods in bean was noted by Vieira *et al.* (2009) when intercropped with maize than in sole crop of bean. Schoeny *et al.* (2010) noted that ascochyta blight (*Mycosphaerella pinodes*) severity on pea was less in pea-cereal intercropping system than monocropped pea because of modification of the microclimate within the canopy of the intercrop combinations.

Weed control is one of the important aspects in intercropping as because chemical control is problematic once different crops are emerged. Generally, cereal-legume is the best intercrop combination and widely practices. Otherwise if there is any combination of dicotyledonous and monocotyledonous crop species weed management by application of chemical herbicide is quite difficult. However, intercrops show weed control advantages over sole crops by expressing greater crop yield and less weed growth which are due to more coverage of land resource by crop combinations (Olorunmaiye 2010) or suppression of the growth of weeds through allelopathy. Intercrops suppress weeds by occupying greater share of available resources than sole crops and can be more effective in pre-empting resources by weeds and suppressing weed growth. A significant reduction in weed population and biomass production for the wheat/chickpea intercrops over both monocrops of wheat or chickpea was found (Banik *et al.* 2006). Moreover, it was reported that intercropping maize with legumes considerably reduced weed density in the intercrop compared with sole crop of maize due to non-availability light for weeds in the maize-legume intercropping system, which led to a reduction of weed density and weed dry matter compared with sole crops (Bilalis *et al.* 2010).

Promotion of biodiversity in agriculture

Intercropping includes biodiversity into agro-ecosystems and increased crop diversity may enhance the number of ecosystem services provided. Richness in crop species may be associated with nutrient cycling that may regulate soil fertility (Russell, 2002), limit nutrient leaching losses (Hauggaard-Nielsen *et al.* 2003), and significant reduction in terms of the negative impacts of pests and diseases population dynamics (Bannon and Cooke 1998; Fininsa 1996), less incidence of weeds growth (Hauggaard-Nielsen *et al.* 2001) leading to agricultural sustainability. Intercropping makes a cut in single crop environment by promoting biodiversity which ultimately promotes diversity in habitat for a variety of insects and soil organisms. Sustainable as well as stable natural systems are diverse in nature, containing various plant species, arthropods, beneficial and harmful insects, mammals, birds, and microorganisms. As a result, in stable and sustainable systems, serious pest outbreaks are rare because of presence of natural enemies to control pest population dynamics and biological balance (Altieri 1994). In this way, creation of on-farm biodiversity by adoption of intercropping systems can lead to sustainable agro-ecosystems enable to maintain soil fertility, regulate natural protection against pests and assure productivity (Scherr and McNeely 2008). Further, increasing the complexity of the crop environment by adoption of intercropping system may restrict the places where pests can get their optimal foraging or suitable reproductive conditions. In this way diversity in crop species through intercropping benefits ecosystem services and sustainability in crop production.

CONCLUSION

Some researchers express their opinion that intercropping is suitable only for small and marginal farmers as well as for them who are involved in subsistence farming. But, it has already been observed in different corners of the world that traditional farmers developed polyculture in farming which are more fit to the local conditions to attain production sustainability (Denevan 1995). Further, intercropping has been an important production practice in many developing countries (Clawson, 1985). In most of the multiple cropping systems by smallholders, farm output can be maximized per unit area by adoption of intercropping due to reduction of pest incidence and more efficient use of nutrients, land, water and solar radiation. Intercropping has a huge potential and multiple advantages. So far mainstream agronomic research has largely focused on sequential cropping systems. Thus, there is a need of more research to better understand the functioning of intercrops and to develop more and more intercropping options compatible with current farming systems targeting a better and sustainable harvest.

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