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Intercropping Systems in Sustainable Agriculture

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Abstract: Different systems have been investigated that can increase the yield to be taken from agriculture area in order to increase the crop production decreasing with the decrease of the agricultural areas available in the worldwide. One of these systems is intercropping. Intercropping is characterized as production of two or more different crop species at same time on the same piece of land. Intercropping is one of the most effective methods in agricultural production with a long history. It is known as the achievement of a high and stable production that not only raises complementary products in the area but also reduces the harmful effects of diseases and pests, prevents pollution and results in effective use of resources. In this review study, it is informed about the use and importance of the intercropping system which is mainly based on very old ones and which is of great importance in recent years in agricultural production.

Key words: Intercrop, sole cropping, use of land, diversity

Sürdürülebilir Tarımda Birlikte Yetiştiricilik

Özet: Dünya genelinde azalan mevcut tarım alanlarına paralel olarak, azalan üretimi artırmak için verimi artıran farklı sistemler araştırılmaktadır. Bu sistemlerden biri de birlikte yetiştiriciliktir (intercropping). Intercropping aynı birim alanda asıl yetiştiriciliği yapılan bitkinin sıra aralarında yetiştiriciliği yapılan, bir veya daha fazla benzer olmayan bitkinin birlikte yetiştirilmesi olarak tanımlanmaktadır. Birlikte yetiştiricilik sistemi tarımsal üretimde çok uzun bir geçmişe sahip olan etkili yöntemlerden biridir. Sadece birim alanda tamamlayıcı ürünlerin yetiştiriciliği değil, aynı zamanda hastalıkların ve zararlıların olumsuz etkilerini azaltan, kirliliği önleyen ve kaynakların etkili kullanılmasını sağlayan yüksek ve istikrarlı bir üretim şekli olarak bilinmektedir. Bu derleme çalışmasında, temelde çok eskilere dayanan ve tarımsal üretimde son yıllarda büyük önem arz eden intercropping sisteminin kullanımı ve önemi hakkında bilgi verilmektedir.

Anahtar kelimeler: Birlikte yetiştiricilik, tek ürün, alan kullanımı, çeşitlilik

Introduction

Globally, cultivable land has decreased due to population increase and industrialization. Particularly in Asia and Africa where producers have small plots, agricultural areas are under pressure to produce for human nutrition (Awal et al., 2007). While global demand for food increases, agricultural expansion faces more stringent environmental preservation demands and sustainability laws aimed to prevent deforestation (Crusciol et al., 2014). Industrialization and globalization in agriculture and food supply endanger the future of humanity and environment. Industrial agriculture based on agrochemical use has negative impact on human health, ecosystem and food quality (Altieri and Nicholls, 2005). Furthermore, although modern industrialized agriculture based on monoculture has resulted in high increased yields, it caused huge costs.

A huge amount of energy requires for production the synthetic of fertilizers and pesticides. Moreover, agrochemicals can cause environmental degradation and disruption and human health risks. Many scientists nowadays are getting worried about the environmental and health risks of industrialized agricultural practices, and they are reconsideration low-technology alternatives (Horwith, 1985). Sustainable agriculture aims to simulate nature as the pattern for designing agricultural systems an important principle for sustainable agriculture is to create and maintain diversity, integrating plants and animals into a diverse landscape (Oad et al., 2007). In sustainable agriculture, it is essential to provide needs of people today and future generations. Diversity and its effective management for sustainable agriculture are very important (Shaker-Koohi et al., 2014). Intercropping suggests farmers the chance to simulate nature's principle of diversity on their farms. Intercropping can be a method to improve diversity in agricultural ecosystem.

The intercropping systems are old and widespread applications in low-input agricultural systems in tropical regions and they were common for developed countries before the modernization of agriculture (Hauggaard-Nielsen and Jensen, 2005). It has been reported the benefits of intercropping in some crops which can cause to efficient land use as an important component of sustainable agriculture (Yildirim and Guvenc, 2005; Karlidag and Yildirim, 2009a; Eskandari and Ghanbari, 2009).

The growing population has compelled agricultural planners to recheck the role of intercropping, the application of growing more than one crop in a field at the same time, as a tool to enhance agricultural production and to obtain efficient land use (Midmore, 1993). Cropping of several plant species together reduces negative effects of a monoculture and thus is commonly employed in ecological agricultural systems. Agricultural practices like intercropping are pro ecological; supporting bio-diversity and is compatible with the principles of balanced agriculture. Intercropping has recently being discovered again due to popularity of organic agriculture (Blazewicz-Wozniak and Wach, 2011).

Andrews and Kassam (1976) defined the intercropping as the agricultural practice of growing two or more species in the same land at the same time. Intercropping is bottomed on the management of crop interactions to optimize growth and productivity. The recommended optimum plant density of the main crop is cultivated with appropriate additional plant density of the inter-crop (Takim, 2012; Chandra et al., 2013; El Naim et al., 2013; Aminifar and Ghanbari, 2014). Intercropping has important advantages in regard to efficient land use, increasing crop productivity and monetary returns thanks to effective use of various inputs compared to sole cropping. Crops and their agronomic characteristics used in intercropping systems are very crucial.

Component crops having different harvest time should be preferred to reduce competition for similar resources at the same time. Moreover, different root and above ground parts of plants used in intercropping systems can be advised for effective utilization of moisture and light. The intercrops should have either synergistic or complementary effect relative to the main crop (Kumar et al., 2010). Success of intercropping systems over sole cropping can be achieved by some agronomic manipulations. These manipulations can be plant density, planting time, available resources and intercropping patterns (Mousavi and Eskandari, 2011). Spatial arrangements, planting and harvest times of crops should be taken into account in intercropping systems. There are several intercropping systems such as mixed, strip and row intercropping patterns (Oad et al., 2007). Supplemental effects in models of resource use should be considered to get better yield and quality in intercropping systems. Cultivars to be determined for intercropping systems should improve the complementary effects between species (Baumann et al., 2001).

Intercropping systems are widely used in Latin America, Asia, and Africa where capital investment is restricted, minimizing risk of total crop failure (Francis 1989; Legwaila et al., 2012). Many different intercropping patterns are practiced all of over the world that farmers employee the different crops and management practices to supply their requirements for food, fiber, medicine, fuel, building materials, forage, and cash. Annual crops with other annuals, annuals with perennials, or perennials with perennials can be grown in intercropping practices (Liebman and Dyck, 1993). The benefit of intercropping in the nursery is yet to receive the necessary research attention. There have been studied to determine the effect of different intercropping models on plant growth, yield, land equivalent ratio and economic returns in young tree-vegetable intercropping. These studies indicated that sapling-vegetable intercrop treatments could result in higher total yield as well as profitability (Ojeifo et al., 2007a; Ojeifo et al., 2007b: Karlidag and Yildirim, 2009a).

Intercropping can significantly increase total productivity as compared to sole cropping thanks to better utilization of water, nutrients and solar energy, (Yildirim and Guvenc, 2005; Matusso et al., 2014). Agricultural sustainability encourages the intercropping practices because they can improve soil conservation and soil fertility, has more stable yields and potential for pest and disease control (Guvenc and Yildirim, 2006). Intercropping systems have been reported to be one of the agricultural practices to control soil erosion (Sharaiha and Ziadat, 2007).

Intercropping for More Effective Use of Resources

Agricultural planners have taken attention to intercropping systems, which decrease inputs in sustainable agriculture due to exploit natural resources more effectively (Ouma and Jeruto, 2010). Intercropping systems have been reported to increase total productivity since it utilizes nutrient elements in soil more efficiently than sole cropping (Eskandari, 2011; Mobasser et al., 2014). One of the goals of the intercropping is to improve total productivity in a particular area by improving resources use efficiency. Crops in these systems use available resources more efficiently thanks to different rooting and canopy properties which component plants species exploit resources complementary (Lithourgidis et al., 2011; Moradi et al., 2014).

Intercropping practices have complementary effect for plants used in regard to resources use, which effectively utilizes solar radiation, water and nutrient elements as compared to pure cropping (Eskandari, 2011). The successful intercropping applications improve to partake the available resources over time and space, using the differences between crops used in intercropping in terms of canopy growth rate, canopy and root structure (Midmore, 1993). Complementary effects of intercrops can be expressed as complementary resource use and niche differentiation in space and time, thus reducing competition between crop species and improving greater acquisition of limiting resources (Li et al., 2014).

There are direct and indirect facilitative interactions of intercropping systems. Intercropping systems can cause more effective use of resources by providing symbiotic nitrogen from legumes, or making available inorganic phosphorus fixed in soil because of lowering of pH via nitrogen fixing legumes (Jensen, 1996a; Aminifar and Ghanbari, 2014). Zhou et al. (2000) suggested that intercropping could enhance nitrogen utilization. Nitrogen fixation by a legume crop can be the cheapest and the easiest way for supplying nitrogen to the non-legume in intercropping systems. Many studies reported that legume plants might provide biologically fixed nitrogen to the non-legume ones (Karlidag and Yildirim, 2009b). Moreover, intercropping systems can reduce the nitrate leaching from the soil profile since intercropping systems utilize soil nutrient elements more efficiently than pure stands (Zhang and Li, 2003). Whitmore and Schröder (2007) concluded in their study that the yield and profitability of intercropping systems can be contrary correlated to the residual nitrate at harvest and intercropping systems can be used to reduce nutrient pollution from agricultural practices as keeping yields. Sobkowicz and Sniady (2004) reported that triticale-bean intercropping system resulted in more benefit for nitrogen uptake than for total yield. Higher nitrogen uptake by intercropping than by sole cropping suggested that intercrops separately utilized different sources of nitrogen, which indicated complementary usage of nitrogen in intercropping systems.

Root interactions in intercropping systems results in nitrogen transfer form legume crops to non-legume ones and exploitation of the soil through mycorrhizal fungi and various soil-plant relationships. These soil-plant interactions greatly modify the mobilization of resources via exudation of amino acids and plant growth promoting matters, extracellular enzymes, acidification and competition-induced modification of root properties (Hauggaard-Nielsen and Jensen, 2005). Some legume crops have been reported to fix atmospheric nitrogen as well as improve availability of phosphorus, thus improving total yields (Snapp and Silim, 2002). Mobesser et al. (2014) indicated that intercropping has improved nutrient uptake like phosphorus.

There is evidence that some legume species can solubilize fixed phosphorus by modifying the chemistry of their rhizosphere, making it available for uptake (Hauggaard- Nielsen and Jensen 2005). Cereals-legume intercropping practices can be an effective way for improving the acquisition of soil resources such as nitrogen and phosphorus. The suggested hypothesis can be that different intercrop species can use different phosphorus pools, the legume being responsible for greater changes in phosphorus availability in the rhizosphere, as a result of root-induced acidification from nitrogen fixation (Betencourt et al., 2010). Nutrient uptake of plants with different root architects in intercropping systems is higher than sole cropping as their root characteristics explores a larger soil mass. The capability of an intercropping system use for plant nutrient elements is affected from the extent of root growth of intercrops. Complementary usage of resources can be more effective when used crops with different root characteristics (Midmore, 1993).

Competition for nutrient elements can be reduced in intercropping systems by choosing crops with different rooting characteristics, nutrient requirements, and timing of peak demand for nutrients. Nutrient competition is reflected by lower nutrient content in plant parts (Varghese, 2000; Morris and Garrity, 1993). Many earlier studies pointed out that the nutrient contents of plants in intercropping practices were similar to the ones in sole cropping, indicating the efficient use of available resources by intercrops (Santos et al., 2002; Yildirim and Guvenc, 2005; Guvenc and Yildirim, 2006; Yildirim and Turan, 2013).

More efficient water usage in intercropping systems was suggested (Moradi et al., 2014). Kanton and Dennet (2004) pointed out that intercrops produced more dry matter than sole. Intercropping systems reduce wind speed, provide shade and increase infiltration, so conserving soil water and improving soil structure. The different root architects of intercrops influence water uptake and the capability of plants to reach for water resources. Maize-cowpea intercropping systems enhanced light interception, decreased water evaporation and conserved the soil water when compared to sole maize cropping, and therefore had consistently greater water use efficiencies (Mobesser et al., 2014). Studies on rhizosphere processes and nutrient use in intercropping systems have proved a lot of physiological indicator for interspecific facilitation among crops (Li et al., 2014). Furthermore, earlier studies reported that intercropping systems could improve light interception and increase shading compared with mono cropping, lower water evaporation and conserve of soil water (Ghanbari et al., 2010).

In intercropping systems arbuscular mycorrhizal mycelia may interconnect from one crop root to another crop roots (He et al., 2003). Jensen (1996b) suggested that plant nutrient elements such as phosphorus and nitrogen emerging from arbuscular mycorrhizal hyphae elevated with time because of accelerating turnover of hyphae and rich phosphorus root materials. Moreover, He et al. (2003) showed one-way transfer of from leguminous nitrogen to non-nitrogen fixing mycorrhizal ones and transfer from non-nitrogen fixing crops to nitrogen fixing mycorrhizal ones as a kind of two-directional transfer approach.

Long-season plants slowly grow and establish a full canopy, which provide an opportunity for short-season plants to be produced between long-season plant rows (Fukai and Trenbath, 1993). Some available resources such as solar radiation, water and nutrient elements may efficiently be used by a component plant grown between the rows of long-season plants (Midmore, 1993). Intercropping systems of crops having different under and above ground characteristic, and growth span have been reported to be more productivity, profitable and utilize the resources such as water and nutrient elements than mono cropping (Vargeshe, 2000; Yildirim and Guvenc, 2005, Karlidag and Yildirim, 2009b).

Intercropping for More Stable System

Being able to sustain total yield and economic return is a more essential goal for producer with very restricted resources than to maximize productivity or economic return. Additionally, the family goals can be considered as supplying food and income throughout the year, reducing the risk of failure at all times, keeping cash costs to a minimum, and fulfilling social involvements in the community (Fukai and Midmore, 1993). Studies have affirmed usage of intercropping systems as one of the crop production alternatives in case of crop failure in mono cropping and have been declared worldwide as one of the most dependable ways to maintain the sustainability of crop production (Coolman and Hoyt, 1993). Some plants can improve unsuitable environmental conditions and the availability of resources for other ones (Lambers et al., 1998).

Plants differently respond to environmental stress conditions, and it is not rare for one plant species to do poorly while a different plant is grown under the same conditions (Horwith, 1985). There is a increasing of interest on intercropping practices since the benefits of intercropping practices are limited to low-input and small-scale agricultural practices (Baumann et al., 2001). Itulya et al., (1997) suggested intercropping practices could be consonant with mechanized agriculture and an alternative to sole cropping, particularly for small, resource-limited farmers.

Intercropping practices have been reported to increase total yields and as well as a useful way of reducing risk: if one crop fails another can still provide sufficient food until the next harvest (Whitmore and Schröder, 2007). Guvenc and Yildirim (2006) indicated that intercropping practices could be more stable systems of agricultural practices than mono cropping for farms, which are low-input and small-scale. This might be attributed that the yield from one intercrop meets for decreasing in yield of another crop (Zimmermann, 1996).

Increasing Productivity with Intercropping Systems

One of the most important causes for growing two or more crops at same time is to maximize total yield per unit of area. Intercropping practices can increase total productivity by using natural sources effectively on condition that intercrops requirements for sources are fulfilled. Management of component crops to increase their complementary effects, and to decrease competition depends on simple natural rules, and its practice is limited only by the imagination of farmers and agronomists (Midmore, 1993).

The sustainability of any production system can be affected by the economic income, assessing the feasibility of different cropping practices. Many researches showed that intercropping practices can ensure higher yield as well as productivity and profitability in crops per unit land (Emuh et al., 2006; Karlidag and Yildirim, 2007; Yildirim and Turan 2013). This phenomena could be expressed via the effective usage of available sources per unit land for inter crops (Sharaiha and Hattar, 1993). Intercropping could be not only use limited areas for crop production more efficiently but also increase income. Higher returns under intercropping systems explained the suitability of intercropping systems to be adopted on a commercial scale (Yildirim and Guvenc, 2005; Karlidag and Yildirim, 2007; Karlidag and Yildirim, 2009b; Mahant et al., 2012). Rehman et al. (2010) determined that the maximum net farm and cost-benefit ratio was obtained from maize intercropped with cowpea compared to the sole crops.

Previous works have showed that the land equivalent ratio (LER) generally was determined as higher one. LER values are accepted as an index of biological efficiency of intercropping systems (Baumann et al., 2001; Yildirim and Guvenc, 2004; Guvenc and Yildirim, 2005; Yildirim and Guvenc, 2005; Karlidag and Yildirim, 2007; Yildirim and Turan, 2013). If land equivalent ratio (LER) values of intercropping practices are higher than one, this generally means intercropping efficiency over the mono cropping (Vandermeer, 1989). Intercropping practices are the most productive when intercrops of different growth period are used so that their maximum requirements for growth resources occur at different times (Fukai and Trenbath, 1993).

Earlier studies supported the advantages of intercropping systems over mono cropping (Karlidag and Yildirim, 2009a; Yildirim and Turan, 2013). Intercropping systems can use present sources and be more effective especially if inputs such as water and nutrients are given to the plants in suitable quantity and time (Abusuwar and Al-Solimani, 2013). The differences of harvest time, root and above ground properties or intercrops resource usage can decrease competition among intercrops due to complementary effect of them (Sharaiha and Hattar, 1993).

Intercropping for Pest, Disease and Weed Control

Intercropping is the one of the integrated pest management tools to reduce population densities of pests in field grown crops (Theunissen, 1997). Integrated pest management studies have increased interest in cultural control methods and these have extended to include agro-ecosystem management. Intercropping practices have been reported to have positive effect on insect, disease and weed control (Theunissen, 1997; Baumann et al., 2000). Intercropping systems have been determined to reduce the populations of numerous herbivore species under a wide range of conditions. The component crop may also serve as a host for natural enemies of pests of the other crops (Vandermeer, 1989). Hauggaard-Nielsen et al., (2008) determined barley-grain legumes (pea, faba bean, and lupine bean) intercropping practices decreased the disease incidence when compared to the corresponding mono crops, with a general disease reduction in the range of 20–40%.

Keeping a full plant cover on the soil will prevent the weed germination and reduce weeds population. Spatial regulations, physical and temporal barriers, microclimate modification, odor effects, and color and trapping effects between intercrops influence insect or disease situation or their natural enemies (Midmore, 1993). Diversity in agricultural ecosystems may restrict pathogenic epidemic. Intercropping practices raises biodiversity as natural ecosystems. Raising diversity can decrease negative effect of insect and diseases (Anil et al., 1998).

There are three hypothesis suggested for decreasing negative effect of insect and diseases; a) limiter crop hypothesis: one intercrop breaks down the ability of a pest in attack to its host, b) trap crop hypothesis: one intercrop species, attracted towards their, pest or pathogen that normally does damage to the main species, c) “natural enemies” hypothesis: predators and parasites can be more present in intercropping practices than sole cropping (Aminifar and Ghanbari, 2014)

Crop rotation and intercropping practices can decrease weed population density and biomass yield. Intercropping systems have weed control advantages over mono cropping systems. This can be attained when intercropping practices are more effective than mono cropping in capturing sources from weeds or suppressing weed growth through allelopathy. Furthermore, intercropping systems can have some advantages without suppressing weed growth below levels determined in component crops if intercrops utilize sources that are not exploitable by weeds or convert resources to harvestable parts more efficiently than sole crops (Liebman and Dyck., 1993).

Available natural resources in sole cropping practices can effectively not utilized by plant, thus capturing by weeds. Intercropping practices with more and effective use of ecological sources, and filling the empty niche, leads to weed control are better and effective than the sole cropping practicing (Altieri, 1995; Aminifar and Ghanbari, 2014). The exudation of some growth regulating matters can contribute greatly to the competitive interactions between intercrops including weeds and thus affect the final intercrop composition (Hauggaard- Nielsen and Jensen, 2005). Aghaalikhani et al. (2009) determined that complementarily effect of corn/soybean intercropping created better condition for optimum utilization of solar radiation to successfully suppress weeds and maintain crop production.

Conclusions

Intercropping systems can be characterized by interactions among component plant species that can affect growth and yield of plant species used (Vandermeer, 1989). In general, the studies of intercropping which have done by researchers over the world, have indicated that intercropping practices could be more productivity than mono cropping, which was suggested this to facilitative relationships in intercropping. With better understanding of these interactions, we may manage to get higher productivity and resource use efficiency in agro ecosystems. The results of the many studies concluded that intercropping could be a profitable, which resulted in more total productivity and economic gains as compared to mono cropping. The urges of sustainable agricultural practices and the environmental problems sourcing from current agricultural practices have had intercropping systems reconsidered. It should be continued study on the possibilities of growing more than one crop in a given area at the same time many advantages of intercropping systems (Lithourgidis et al., 2011).

The extent of increasing crop productivity via appropriate intercrop patterns has not yet been utilized to its full potential. Complementarities in models of resource use should be considered to get better productivity in intercropping systems. Cultivars to be used in intercropping systems should improve the complementary effects between crops. Furthermore, to obtain advantageous of intercropping it is important to determine species or cultivars, and spatial geometry and planting density of component plants used intercropping.

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