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INTERCROPPING - AN OPPORTUNITY FOR SUSTAINABLE FARMING SYSTEMS. A REVIEW

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Abstract

As population expansion, urbanization, environmental pollution, and climate change, the global food crisis is currently aggravated in the world. One strategy for coping with the effects of climate change in arid regions is intercropping. The purpose of this paper is to review the main types of intercropping- Row intercropping, Mixed intercropping, Strip intercropping, Relay intercropping and present their advantages. Intercropping is as a multiple cropping system, in which two or more crops species planted simultaneously in a field during a growing season. An example of sustainable farming systems is intercropping, which creates balance with the environment, contributes to better use of resources, and reduces damage from diseases and pests. Potential advantages of this practice include higher crop yields- due to extra sunlight that taller crops receive on their borders. Intercropping enables plants to efficiently utilize plant growth resources like water, nutrients, sun light; to improve soil erosion control. Intercropping patterns are more effective than monocropping in suppression of weeds, but their effectiveness varies greatly. Intercropping is ways to increase diversity in an agricultural ecosystem.

Key words*: agroecosystem; intercropping; sustainable agriculture.*

INTRODUCTION

Intercropping has a vast potential for sustainable agriculture, as it provides 15-20% of the world's food supply (Lithourgidis et al., 2011) and contributes to reducing the contradiction between population growth and the reduction of arable land (Fowler et al., 2015). By increasing the yields of some cereals, the Green Revolution has so far permitted humans to cope with population growth (Pingali, 2012), and its new technologies are still central to ongoing reduction in the total number of undernourished people (Martin-Guay et al., 2018). Lithourgidis et al., (2011) point out that according to Altieri, (1999) self-sustaining, low-input and energy-efficient agricultural systems in the context of sustainable agriculture are the focus of many farmers. From an environmental point of view, intercropping looks promising, aiming to have a limited impact on the environment, which is achieved through the sustainable intensification of agriculture, i.e. without any harmful trade-offs between productivity and other ecosystem services (Tilman et al., 2011).

The purpose of this paper is to review the main types of intercropping - Row intercropping, Mixed intercropping, Strip intercropping, Relay intercropping, and to present their advantages. An attempt is made to present the advantages of intercropping, which creates a balance with the environment and contributes to the better use of resources.

MATERIALS AND METHODS

This review article summarizes the results from researchers conducting intercropping experiments. The studies are multi-layered and highlight the role of intercropping in maintaining environmental balance.

A number of authors emphasize the role of intercropping in the direction of diversification and suggest various ways to arrange crops in the agroecosystem to make it more sustainable.

A comparison is made between crop monoculture with intercropping and the advantages it brings, namely increased crop yield, efficient utilization of agricultural resources and competition for resources between species.

Intercrops improve soil fertility and make the intercropping-based agri-horti system ecologically sustainable and economically feasible to farmers.

RESULTS AND DISCUSSIONS

Intercropping is an old cropping system, which dates back to ancient civilization (Nasar et al., 2019) and has a long history (Ghaffarzadeh, 1999; Bybee-Finley & Ryan, 2018; Feng et al., 2021), being practiced to achieve higher yields and to satisfy the world's demand for food (Vandermeer, 1990; Connolly et al., 2001; Dakora & Phillips, 2002; Zhang & Li, 2003; Zhang et al., 2003; Zhang, 2004; Nasar et al., 2019). An example of sustainable farming systems is intercropping, which creates a balance with the environment and contributes to the better use of resources (Mousavi & Eskandari, 2011). Improving crop diversity on a piece of land through intercropping is one of the adaptation strategies to climate change in drylands (Jaya & Rosmilawati, 2017) and is an opportunity to cope with the effects of climate change (Liu et al., 2016). Intercropping is one form of crop diversification that is meant to spread the risk of crop failure on a single piece of land (Jaya & Rosmilawati, 2017), and intercropping as a practice has survived the evolution of agriculture in the semi-arid areas of the tropics (Tignegre et al., 2018; Jun-bo et al., 2018; Godfray et al., 2010; Foley et al., 2011), according to whom as population expansion, urbanization, environmental pollution, and climate change, the global food crisis is currently aggravated in the world. One of the main reasons for the worldwide use of intercropping is the production of more than pure cropping from the same amount of land (Caballero & Goicoechea, 1995; Mousavi & Eskandari, 2011; Šeremešić et al., 2020), with component crops being selected in such a way that they can complement each other in order to achieve better overall resource utilization as compared to when the crops are grown separately (Anon, 2015; Nishanthi et al., 2015). Intercropping combines the temporal and spatial dimensions of crop diversification and offers a variety of ways to shape agroecosystem ecology and productivity (Himanen et al., 2017) and intercropping as a multiple cropping system, in which there are two or more crops species planted simultaneously in a field during a growing season (Vandermeer, 1989; Ariel et al., 2013). The above, however, does not mean that they are planted together at the same time, but that the aim is for two or more crops to be together in one place during their growing season, or at least for a certain period of time (Mousavi & Eskandari, 2011). Intercropping systems help farmers to exploit the principle of diversity (Ghosh, 2004), as they are helpful to avoid reliance on a single crop and result in a variety of products of a different nature, such as forages, oil and pulses (Iqbal et al. 2018b). In 1989 an interdisciplinary research team was set up to develop a more environmentally sustainable cropping system that was also economically favorable (Cruse et al., 1995). Qian et al., (2018) cites Lithourgidis et al., (2011), according to whom intercropping was initially practiced to provide a yield advantage and stability. It also provides possible options for the sustainable intensification of agriculture.

Organic production represents one of the most important sustainable agriculture systems, wherein higher nutritional values of food could be achieved alongside the preservation of biodiversity and agroecosystems (Šeremešić et al., 2017). In organic vegetable cultivation, the proper selection of varieties/hybrids, crop rotation, and intercropping cultivation also play a very important role (Ugrinović et al., 2014) because complementary relationships are created with neighbouring ecosystems and environmental resources are used more fully (Šeremešić et al., 2018). Jones & Sieving, (2006) points out in order for agriculture to evolve towards environmentally sustainable systems (Atkinson & McKinlay, 1997), the cultivation of intercrops (strips within the field), cover crops, field margins, hedgerows, windbreaks that serve ecological functions on farms (i.e. predator refugia) (Nentwig, 1998). Intercropping has always been the most widespread form of cropping system in (sub-) tropical and developing countries (Schulz et al., 2020). Yildirim & Ekinci, (2017) cites authors (Francis, 1989; Legwaila et al., 2012) who point out that intercropping systems are widely used in Latin America, Asia and Africa where capital investment is restricted thus minimizing the risk of total crop failure. Brooker et al., (2015) cites Francis, (1986) who has indicated that smallholder farmers in Latin America grow 70-90% of beans with maize, potatoes and other crops, while maize is intercropped on

60% of the maize-growing areas of the region; according to Vandermeer, (1989) 98% of cowpeas in Africa are grown as intercrops, 90% of beans - in Colombia. The total percentage of cropped land in the tropics used for intercropping varies from 17% in India to 94% in Malawi. In Europe intercropping persists in agroforestry systems, such as the Swiss pâturages boisés (wooded grassland systems) and Mediterranean coltura promiscua (cereals and vegetables grown under trees, often olive and fruit trees or vines) (Dupraz & Liagre, 2011; Brooker et al., 2015). Intercropping has been used in numerous parts of the world (Głowacka, 2013; Chang et al., 2020). Jun-bo et al., (2018) points out authors (Feike et al., 2012; Liu et al., 2013; Zhang et al., 2013), according to whom the limited farmland in China impels people to increase crop yields by using chemical fertilizers, thus degrading the environment and severely polluting the water and air, acidifying the soil and eroding it. Tignegre et al., (2018) cited authors Tsubo et al., (2005) who point out that in many developing countries intercropping is an important practice in subsistence and food production farming systems, as in the Guinea savanna zone of Northern Region of Ghana, a maize is one the most widely grown food staples for intercropping during the humid season. Nishanthi et al., (2015) presents the results from an intercropping system of black gram and *Amaranthus tricolor* L., where black gram is one of the important grain legumes in the rainfed farming system in the dry and intermediate zones of Sri Lanka. Singh et al, (2018) cites Sarkar et al., (2008) who has reported that vegetables, such as chili, brinjal, *Colocasia*, *Amorphophallus* and pumpkin, are the most acceptable intercrops in papaya under West Bengal condition. Singh et al. (1994) suggest that cowpea, peas, turmeric, radish and pawpaws are suitable intercrops for mango orchard.

Intercropping is a way to increase diversity in an agricultural ecosystem (Mousavi & Eskandari, 2011) and traditionally intercropping has been used to increase crop production and land efficiency, as it is also a strategy to mitigate risks (Bybee-Finley & Ryan, 2018). Ariel et al., (2013) reports authors (Liebman & Dyck, 1993; Ren et al., 2008; Gao et al., 2010; Coll et al., 2012) who point out that intercropping systems can provide many benefits through the increased efficiency of land use and by increasing the length of production cycles. Intercropping enables plants to efficiently utilize plant growth resources such as water (Wang et al., 2015; Raza et al., 2021), nutrients (Zhang et al., 2003), sunlight (Nasar et al., 2019) for their growth, which is associated with the better utilization of resources, and the numerous positive effects of growing certain varieties in intercropping systems (Eskandari, 2012; Šeremešić et al., 2018), thus having an impact on plant growth, increasing the biomass production and yield (Zhang et al., 2011). Intercropping is practiced with the aim of maximizing plant cooperation rather than plant competition for maximum crop yields (Sullivan, 2001; Ofosu-Anim & Limbani, 2007). Other advantages of intercropping is the decreased number of pests and weeds (Dolijanović et al., 2008; Mousavi & Eskandari, 2011) and the reduced disease infestation (Ren et al., 2008). The potential advantages of this practice include higher crop yields due to extra sunlight received by taller crops on their borders (Cruse et al., 1995). Qian et al., (2018) reports that nutrient (e.g. nitrogen and phosphorus) transportation is of interest in intercropping systems (Mei et al., 2012; Gao et al., 2014), as the organic matter added by the intercrops improves soil fertility and makes the system more environmentally sustainable (Upadhaya et al., 1994; Singh et al., 2018). Agricultural sustainability encourages intercropping practices, thus reducing wind speed, providing shade and increasing infiltration, which result in retaining water in the soil and improving its structure, fertility and ensuring its conservation (Guvenc & Yildirim, 2006). Yildirim & Ekinci, 2017, cites Mobesser, (2014), according to whom the different root architects of intercrops influence water uptake and the capability of plants to reach for water resources. Maize-cowpea intercropping systems have enhanced light interception, decreased water evaporation and conserved the soil water when compared to sole maize cropping, and therefore have been having consistently greater water use efficiencies. Legumes adapt well to various cropping systems owing to their ability to fix atmospheric nitrogen in symbiosis with the soil bacteria of Rhizobium spp. (Nishanthi et al., 2015) and forage legumes can provide other, less known benefits besides biological nitrogen fixation, such as buffering from weeds, pests and abiotic stresses, support for beneficial biota and higher yields per area (Himanen et al., 2017). There may be a symbiotic cohabitation between the two crops, where intercropping reduces soil erosion due to the optimum soil coverage (Cruse et al., 1995; Zougmoré et al., 2001; Tignegre et al., 2018). Qian et al., (2018) reports that intercropping systems have been proven to have positive effects on the control of wind erosion, weed control (Gronle et al., 2015; Liang et al., 2016) and can simultaneously suppress soil-borne diseases (Boudreau, 2013; Chang et al., 2020). Tignegre, et al. (2018) quotes authors Nampala et al., (2002) stating that insect populations (aphid and thrips) are significantly reduced in cowpea-sorghum intercrops, and that when chili-maize (Gutierrez, 1999) and tomato-maize (Pino et al., 1993) are grown, pests and disease pressure are moderate. Ariel et al., (2013) cites authors Hummel et al., (2009) who indicate that intercropping may be the improved quality of the seed, an improvement of the crop canopy structure susceptible to lodging. The author also points out another advantage reported by Crew & Peoples, (2004), namely that the legumes used contribute to minimizing the inorganic nitrogen fertilizers used and this improves water quality. Tignegre et al., (2018) cites Akunda, (2001) indicating that positive physiological interactions can be accounted for intercropping with sorghum-soybean intercrops density resulting in increases of the soybean seed protein. According to Mousavi & Eskandari, (2011) intercropping can be included for: annual plants with annual plants intercrop; annual plants with perennial plants intercrop; and perennial plants with perennial plants intercrop (Eskandari et al., 2009a). Singh et al., (2018) presents an in-depth literature review on vegetable crops as the most effective and economical intercrops that improve orchard health, food security and prevent soil erosion through orchard floor covers. The author cites Singh et al., (2016), which suggested that shade-loving tuber crops (Colocassia, Elephant Foot Yam, Turmeric and Ginger), which have a great potential to withstand and grow under the canopy of fruit plants, are well-suited in the intercropping system because they have a higher biological efficiency for food production and the highest rate of dry matter production through efficient solar energy transfer. Tignegre et al., (2018) cites authors stating that the practice of vegetable-maize intercropping ensures sustainable production with a minimal risk to satisfy the subsistence and commercial needs (Baker & Norman, 1975; Beets, 1990; Wu et al., 2017), as if one crop fails to be harvested, the farmer has another one that can provide food (Lawson et al., 2013). There is a wide diversity of maize intercropping components, which include soybean (Muoneke et al., 2007; Hugar & Palled, 2008) vegetables (tomatoes, hot pepper, okra), fruit crops (Seran & Brintha, 2010; Ijoyah et al., 2012) in Ghana in the humid season (Tignegre et al., 2018). Planting vegetables by using the intercropping method has many advantages, such as a high economic value, easier cultivation techniques, a lower risk of failure, and more suitable cultivation on marginal land. In terms of competitiveness, this means that components of intercrops are not competitors that occupy the same niche (ecological nest) due to morphological and physiological differences, as the competition between species is less than the competition within species (Vandermeer, 1992). In monocropping systems, all available natural sources, such as light, moisture and nutrients, are rarely used by plants, consequently released nich are captured by the weeds (Mousavi & Eskandari, 2011), that are competitors of the main crop. Preserving weed diversity on farmland provides important ecosystem services and must be carefully managed to limit the negative impact of weeds on crop yields through competition for essential resources (e.g. water, light and nutrients) or even maintaining pests (Gaba et al., 2016; MacLaren et al., 2020). Weeds provide a shelter and food for various taxa of the agroecosystems, either beneficial species for pollination services or crop pests. Therefore, the wise agroecological management of weeds should keep weed species of functional interest for regulation, e.g. biocontrol or trophic resources and cultural services (Gaba et al., 2014). As compared to crop monoculture (sole cropping), intercropping has advantages when it comes to the increase of crop productivity and the efficient use of agricultural resources (Chang et al., 2020; Bourke et al., 2021), as the competition for resources between species is less than the one existing within the same species (Ghaffarzadeh, 1999). Intercropping patterns are more effective than monocropping in suppression of weeds, but their effectiveness varies greatly (Girjesh & Patil, 1991). Mousavi & Eskandari, (2011) points out many authors (Gliessman, 1997; Mazaheri et al., 2006), according to whom success of intercrops in comparison with a pure cropping can be determined by a series of agronomic operations, as interactions between the species will be affected by them. These operations include ultimate density, planting date, resources availability and intercropping models. Jun-bo et al., (2018) adds that as compared to continuous monoculture systems, intercropping systems increase soil biodiversity and soil quality, as they also enhance the nutrient-use efficiency (Wang et al., 2014; Cong et al., 2015). In an article Mousavi & Eskandari, (2011) reports the results of studies by several research teams, which indicate that as compared to pure cropping, intercropping of beans and barley results in higher grain and dry matter yields (Martin & Snaydon, 1982), as well as that the higher dry matter production in wheat and beans intercrops has been more than their pure cropping (Ghanbari & Lee, 2002). A number of authors point out that mixed cropping has implications for the higher yields realized (Jensen, 1996). The yield of sweet corn increases when planted with pea as intercrops due to the better use of environmental resources (Francis & Decoteau, 1993). The advantages of smaller yield were associated with intercrops, where the species had the same growing period and where legumes were combined with small grain cereals, such as wheat or barley, in full mixtures to obtain sustainable yields with reduced nutrient inputs (Werf et al., 2020). The interspecific interactions, both facilitative and competitive, contribute to high yielding, however, the roots are strongly responsible for yield improvement (Ghaffarzadeh, 1999; Ghanbari & Lee, 2003). According to Nasar et al., (2019) and (Dakora & Phillips, 2002; Dakora, 2003; Zhang, 2004) cereal-legume intercropping is a common cropping system, in which cereals get growth and yield advantages from legumes by sharing nutrients and some other unknown resources. The interactions between legumes/cereal mixture interactions (facilitating and competing) are complicated to examine (Maurya & Lal, 1981; De Ridder & Van Keulen, 1990; Jensen, 2003) in the utilization and modification of natural resources. Further research is required to address the interactions (above & below ground) in traditional cropping mixture (Ghaffarzadeh, 1999). Intercrops with maize and beans in different ratios prove that production has increased due to the reduced competition between species as compared to the competition within species (Odhiambo & Ariga, 2001). Mousavi & Eskandari, (2011) cites authors (Eskandari et al., 2009b; Eskandari, 2012) who indicate that the production obtained in intercropping is higher, which is probably due to the higher growth rate, reduction in pests, diseases and weeds and more efficient use of resources due to differences in crop preferences for environmental resources. According to Altieri, (1995) if the plants used in intercropping are complementary in the use of environmental resources, the intercropping system will be more efficient. The study by Soria et al., (1975) shows that intercropping (corn- cassava and beans- cassava) is effective in weed control (Mousavi & Eskandari, 2011). A large number of papers (Ofori and Stern, 1987; Vandermeer, 1992) report that intercropping is divided into the following four groups: Row intercropping, Mixed intercropping, Strip intercropping, and Relay intercropping.

In row intercropping, distinct rows of component crops are clearly identifiable (Crusciol et al., 2012), where there is simultaneous cultivation of two or more crops. Row intercropping is carried out either in additive series (no sacrifice of main crop lines) or replacement series (main crop row is reduced for each intercrop row) (Iqbal et al., 2017; Iqbal et al., 2019). Growing two or more crops simultaneously where one or more crops are planted in regular rows, as the crop or other crops may be grown simultaneously in row or randomly with the first crop (Iqbal et al., 2018a). Another key advantage associated with intercropping is its potential to increase the land productivity per unit area and the efficient utilization of farm resources (Mucheru-Muna et al., 2010). Cereals intercropping with legumes result in the increased resource capture by component crops and improve the soil microbial activity along with a better efficiency of resource conversion, which triggers higher biomass production (Alvey et al*.,* 2003). Wide spacing and slow growing nature during the initial growth period of fennel and ajwain make it possible to raise short duration intercrops in between the rows (Mehta et al., 2017). Singh & Kumar, (2002) points out that the inclusion of radish and fenugreek as intercrop increases the productivity and profitability per unit area in winter maize as compared to growing it as a sole crop. According to Rao & Singh, (1990), an intercropping system improves crop yield and contributes to the eimproved returns in the system (Mehta et al., 2017). Cucumber and okra are among the most important vegetables that farmers grow in Ghana, which are commonly interplanted (Ofosu-Anim & Limbani, 2007).

Mixed intercropping entails the intercropping system, in which seeds of different crops are mixed and sown in a blended form in the same row or broadcasted (Iqbal et al., 2019; Khatiwada, 2000), with no distinct row arrangement. This type can be suitable for grass-legume intercropping in pastures (Mousavi & Eskandari, 2011). A mix cropping system not only enhances crop production and returns but can also help safe the plants from complete failure as compared to mono-cropping (Zhang & Li, 2003; Nasar et al., 2019). Ultimately, there is no row distinction of component crops in mixed intercropping systems (Agegnehu et al., 2006). Plants interact with each other in a mixed cropping system, thus efficiently utilizing facilitative (positive interactions) resources and curtailing competition both in the above and underground plant compartments in order to improve growth and yield (Jose et al., 2000; Rao & Mathuva, 2000; Silwana & Lucas, 2002; Wu, 2012; Nasar et al., 2019). In mixed cropping system, crops will be in direct competitions while capturing the same resources (Ghaffarzadeh, 1999).

Strip intercropping adds a spatial diversity to species across the landscape (Ghaffarzadeh, 1999). In strip intercropping, two or more crops are sown in strips (Iqbal et al., 2019) and grown simultaneously in strips wide enough to accommodate many rows (Li et al., 2001; Jaya & Rosmilawati, 2017) and to allow independent cultivation, but strips narrow enough to allow the crops to be close enough to facilitate interaction between them (Mousavi & Eskandari, 2011). Strip-row intercropping distributes labor requirements more evenly over the growing season, allowing complementary interactions that increase yields (Ghaffarzadeh, 1999). Głowacka (2013) cites many authors (Andrade et al., 2012, Hauggaard-Nielsen et al., 2012; Coll et al. 2012) who state that strip cropping is a form of intercropping used in many regions of the world. Strip cropping is practiced with success by several American farmers (Francis et al, 1986). One model of intercropping is strip intercropping, which has many advantages (Li et al., 2001), as Jaya et al, (2017) points out that the potential of strip intercropping on a dryland has been explored and the productivity advantage of the strip intercropping over monoculture has been calculated. This system protects the soil from water and wind erosion and reduces nutrient and pesticides leaching (Zhang & Li, 2003; Głowacka, 2013). Intercropping, especially in relation to maize and pulse crops, is an old cultivation practice, but has recently been re-practiced in relation to the phenomenon of climate change. The use of intercropping has been found to be an approach in sustainable agriculture (Fung et al., 2019). The shift to strip cropping aims to achieve more sustainable crop production and to preserve the natural nutrient richness of the soil. The relevance of strip cropping is based on the potential for this agronomic practice to help stabilize the agroecosystem due to the less soil erosion, lower levels of residual concentrations of excess nutrients in the soil environment (Gitz et al., 2015), successful weed management, and the development of fewer diseases and pests in strip crops (Hijbeek, 2017). Strip cropping and intercropping are agricultural systems where the diversity of cultures simultaneously cultivated on the field contribute to and encourage agricultural biodiversity (Zhang & Li, 2003). Strip cropping can also limit the occurrence of pests, diseases, and weeds, so that the use of pesticides can be reduced (Ma et al., 2007). In strip intercropping, three or more crops (typically corn, soybeans, and a small grain such as oats or wheat interseeded with a legume such as alfalfa or berseem clover) are grown in contiguous narrow strips of four to six rows each within the same field (Cruse et al., 1995). Strips must be equal in width to accommodate this rotation scheme, and farmers must use a strip width compatible with their equipment (Cruse et al., 1995), and the machinery must be modern (Nowatzki, 2017). The strip intercropping system has a greater production potential than do traditional systems (Ghaffarzadeh, 1999; Nowatzki, et al., 2017). The strip cropping system has clearly been a success and is thought to bring additional ecosystem services, such as nitrogen fixation by legumes and the ability of perennial grass-clover to act as a carbon sink (Juventia, et al., 2021), which warrants consideration when considering climate change mitigation tools within the principles of organic agriculture (Lüscher et al., 2014). Strip cropping is a strategy for dividing individual fields into strips of different crops in order to achieve the same positive effects that are known from standard crop rotation (Rodriguez et al., 2021). If compared to monocropping, strip cropping modifies the soil microbial C/N/P ratios, favors fungidominated communities and promotes plant mycorrhizal symbiosis, thus guaranteeing a higher or comparable crop yield. Examples of strip crops are annuals - winter rye + vetch and corn combined with perennial perennial grass-clover in a strip system with sizes of 6x6 m; alternating rows of Emmer wheat and Celtic beans.

Climate change and the ever-increasing production costs result in challenges for farmers and thus requiring the implementation of better farming practices. Farmers are moving towards applying ecological approaches to sustainable agrocenosis management, such as the less extreme strip-till system of tillage, where the soil surface is tilled in strips of different widths and the area in between is left covered with crop residues. The strip-till technology has the advantages of protecting the soil from erosion, reducing fertilizer rates by up to 30% as a result of targeted fertilizer application, and the more efficient uptake of applied fertilizer; tillage, fertilizer application and sowing are all carried out in one pass, thus reducing fuel costs and the need for labour. Plant residues are left on the soil, between the strips, which leads to an improved soil structure, retaining more moisture for a longer period and at the same time the presence of a well-treated seedbed that warms up faster in spring. The variety of crops that are suitable for cultivation under the strip-till technology is large (Pretty & Bharucha, 2014) and this technology has been applied to almost all row crops - maize, sorghum, soybean, sunflower, canola, sugar beet, etc. (Nowatzki et al., 2017).

Relay-intercropping: Growing two or more crops simultaneously during a part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest. In relay intercropping systems, a second crop is sown in a standing crop that has nearly reached the end of its production cycle, prior to harvest (Reda et al., 2005).

CONCLUSIONS

Intercropping creates a very good opportunity to make better use of available resources - light, water and nutrients, thus increasing the yield of the combined crops. The great advantages of intercropping include protecting the soil against water and wind erosion, reducing nutrient and pesticide leaching, and limiting pests, diseases and weeds. A very important aspect is the improvement of crop diversity on a given piece of land, which benefits the agroecosystem and creates resilience under the conditions of a changing climate.

REFERENCES

Agegnehu, G., Ghizaw, A., & Sinebo, W. (2006). Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *Eur. J. Agron., 25*. 202–207.

Akunda, E.M.W. (2001). Crop yields of Sorghum and soybeans in an intercrop. *J.Food Technol.Afr., 6*(1), 2–4.

Altieri, M.A. (1999). The Ecological Role of Biodiversity in Agroecosystems. *Agric. Ecosyst. Environ.*, *74*. 19–31. http://dx.doi.org/10.1016/ S0167-8809(99)

Altieri, M.A. (1995). Agroecology: the science of sustainable agriculture, second edition. *Publisher: Westview Press.*

Alvey, S., Yang, C.H., Buerkert, A., & Crowley, D. E. (2003). Cereal/legume rotation effects on rhizosphere bacterial community structure in west african soils. *Biol. Fertil. Soils, 37*. 73–82, doi: 10.1007/s00374-002-05.

Andrade, J.F, Cerrudo, A., Rizzalli, R. H., & Monzon, J. P. (2012). Sunflower-soybean intercrop productivity under different water conditions and sowing managements. *Agron. J.*, *104*. 1049–1055.

Anon, A. (2015). Amaranth: Food of the Future. [online]. Available from: http://www.inkanatural. com/en/arti.asp?ref=amaranto-en

Ariel, C. E., Eduardo, O.A., Benito, G. E., & Lidia, G., (2013). Effects of two plant arrangements in corn (*Zea mays* L.) and soybean (*Glycine max L. Merrill*) intercropping on soil nitrogen and phosphorus status and growth of component crops at an Argentinean Argiudoll. *AJAF*, *1*(2), 22–31, doi: 10.11648/ j.ajaf.20130102.11.

Atkinson, D., & McKinlay, R.G. (1997). Crop protection and its integration within sustainable farming systems. *Agric. Ecosyst. Environ*., *64*. 87–93.

Baker, E.F, & Norman, D.W. (1975) Cropping systems in Northern Nigeria, In: Harwood, RR (Eds,). Proceedings of the cropping systems workshop held at the International Rice Research Institute, Loss Banos, Lagoons, Philippines, USA 18-20; 334–361.

Beets, W.C. (1990). Raising and sustaining productivity of smallholder farming systems in the tropics. Alkmaar, Holland: *Ag Bé Publishing, 754*.

Betencourt, E., Duputel, M., Colomb., B., Desclaux, D., & Hinsinger P. (2012). Intercropping promotes the ability of durum wheat and chickpea to increase rhizosphere phosphorus availability in a low P soil. *Soil Biol Biochem, 46*. 181–190.

Boudreau, M.A. (2013). Disease in intercropping systems. *Annu. Rev. Phytopathol*, *51*. 499–519.

Bourke, P. M., Evers, J. B., Bijma, P., van Apeldoorn, D.F., Smulders, M. J. M., Kuyper, T. W., Mommer, L., & Bonnema, G. (2021). Breeding Beyond Monoculture: Putting the Intercrop *Into Crops,12*. 1–17, doi: 10.3389/fpls.2021.734167.

Brooker, R.W., Bennett, A.E., Wen-Feng, C., Daniell, T.J., George, T. S., Hallett, P.D., Hawes, C., Iannetta, P.P. M., Jones, H. G., Karley, A.J., Li, L., McKenzie, B.M., Pakeman, R. J., Paterson, E., Scheob, C., Shen, J., Squire, G., Watson, Ch.A., Zhang, Ch., Zhang, F., Zhang, J., & White, Ph.J. (2015). Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. *New Phytologist*, *206*. 107–117, doi: 10.1111/nph.13132.

Bybee-Finley, K. A., & Ryan, M.R. (2018). Advancing Intercropping Research and Practices in Industrialized Agricultural Landscapes. *Agriculture*, *8*(6), 80; https://doi.org/10.3390/agriculture8060080**.**

Caballero, R. & Goicoechea, E.L. (1995). Forage yield quality of common vetch and oat sown varing seeding ratios and seeding rates of vetch. *Field Crops Res.,* 41, 135-140.

Chang, X., Yan, L., Naeem, M., Khaskheli, M. I., Zhang, H., Gong, G., Zhang, M., Song, C., Yang, W., Liu, T., & Chen W. (2020). Maize/Soybean Relay Strip Intercropping Reduces the Occurrence of Fusarium Root Rot and Changes the Diversity of the Pathogenic Fusarium Species. *Pathogens, 9*. 211, doi:10.3390/pathogens9030211.

Coll, L., Cerrudo A., Rizzalli R., Monzon J.P. & Andrade F.H. (2012). Capture and use of water and radiation in summer intercrops in the south-east Pampas of Argentina. *Field Crops Res.*, 134, 105-113.

Cong, W.F., Hoffland, E., Li, L., Six, J., Sun, J.H., Bao, X.G., Zhang, F.S., & van der Werf, W. (2015). Intercropping enhances soil carbon and nitrogen. *Global Change Biology*, *21*. 1715–1726.

Connolly, J., Goma, H.C., & Rahim, K. (2001). The information content of indicators in intercropping research. *Agric. Ecosyst.Environ.*, *87*(2), 191–207.

Crew, T.E. & Peoples, M.B. (2004). Legume versus fertilizer source of nitrogen: ecological tradeoffs and human needs. *Agric. Ecosyst. Environ.*, *102*. 279–297,

Crusciol, C. A. C., Mateus, G. P., Nascente, A. S., Martins, P. O., Borghi, E., & Pariz, C. M. (2012). An innovative crop-forage intercrop system: Early cycle soybean cultivars and palisade grass. *Agronomy Journal,* 104, 1085–1095. http://doi.org/10.2134/ agronj2012.0002

Cruse, R.M, Ghaffarzaden M., & Swan J.B. (1995). Strip intercropping, In: *Proc. Clean Water- Clean Environment- 21 Century*, 3, 73–76.

Dakora, F.D. & Phillips D.A. (2002). Root exudates as mediators of mineral acquisition in low-nutrient environments. *In Food Security in Nutrient Stressed Environments: Exploiting Plants' Genetic Capabilities,* 201–213.

Dakora, F.D. (2003). Defining new roles for plant and rhizobial molecules in sole and mixed plant cultures involving symbiotic legumes. *New Phytologist*, *158*. 39–49.

De Ridder, N., & Van Keulen, H. (1990). Some aspects of the role of organic matter in sustainable intensified arable farming systems in the WestAfrican semi-arid-tropics (SAT). *Fertilizer research*, *26*(1-3), 299–310.

Dolijanović, Ž., Oljača, S., Simić, M., & Kovačević, D. (2008). Weed populations in maize and soybean intercropping. In *Proceedings. 43rd Croatian and 3rd Int.Sym.Agriculture,* 563–567. Opatija, Croatia.

Dupraz, C., & Liagre, F. (2011). Agroforesterie- des arbres et des cultures, *2nd edn. Paris, France: Groupe France Agricole.*

Eskandari, H., Ghanbari A.& Javanmard A. (2009a). Intercropping of cereals and legumes for forage production. *Notulae Scientia Biologicae*, *1*. 07–13.

Eskandari, H., Ghanbari-Bonjar A., Galavai, M. & Salari, M. (2009b). Forage quality of cow pea (*Vigna sinensis*) intercropped with corn (*Zea mays*) as affected by nutrient uptake and light interception. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *37*. 171–174.

Eskandari, H. (2012). Intercropping of Maize (*Zea mays* L.) with Cowpea (*Vigna sinensis*) and Mung Bean

(*Vigna radiate*): Effects of Complementarity of Intercrop Components on Resources Consumption, Dry Matter Production and Legume Forage Quality. *J. Basic Appl.Sci.Res.*, *2*. 355–360.

Feike, T., Doluschitz, R., Chen, Q., Graeff-Hönninger, S., & Claupein, W. (2012). How to Overcome the Slow Death of Intercropping in the North China Plain. *Sustainability*, *4*(10), 2550–2565.

Feng, L., Yang, W., Zhou, Q., Tang, H., Ma, Q., Huang, G., & Wang, S. (2021). Effects of interspecific competition on crop yield and nitrogen utilisation in maize-soybean intercropping system. *Plant Soil Environ.*, *67*(8), 460–467.

Foley, J.A. et al. (2011) Solutions for a cultivated planet, *Nature, 478*. 337–42.

Fowler, D., Steadman, C.E., Stevenson, D., Coyle, M., Rees, R.M., Skiba, U.M., Sutton, M.A., Cape, J.N., Dore, A.J., Vieno, M., Simpson, D., Zaehle, S., Stocker, B.D., Rinaldi, M., Facchini, M.C., Flechard, C.R., Nemitz E., Twigg, M., Erisman, J.W., Butterbach-Bahl, K., & Galloway, J.N. (2015): Effects of global change during the 21st century on the nitrogen cycle. *Atmos.Chem.Phys.Discuss.*, *15*. 13849–13893.

Francis, C.A. (1989). Biological Efficiencies in Multiple-Cropping Systems. Advances in Agronomy, *42*. 1– 42.

Francis, R. & Decoteau, D.R. (1993). Developing an effective southernpea and sweet corn intercrop system. *Hort Technology*, *3*. 178–184.

Francis, C., Jones, A., Crookston, K., Wittler, K., & Goodman, S. (1986). Strip cropping corn and grain legumes: a review. *Am. J. Alt. Agric*., *1*. 159–164.

Francis, C.A. (1986). Introduction: distribution and importance of multiple cropping. In: Francis CA, ed. Multiple cropping systems. New York, NY, USA: *MacMillan Publishing Co*., 1–19.

Fung, K. M., Tai, A. P. K, Yong, T., Liu, X., & Lam, H. (2019). Co-benefits of intercropping as a sustainable farming method for safeguarding both food security and air quality. *Environ.Res. Lett.*, *14*. 044011.

Gaba, S., Fried, G., Kazakou, E., Chauvel, B., & Navas, M. L. (2014). Agroecological weed control using a functional approach: a review of cropping systems diversity. *Agron. Sustain. Dev.*, *34*. 103–119, doi: 10.1007/s13593-013-0166-5.

Gaba, S., Reboud, X.& Fried, G. (2016). Agroecology and conservation of weed diversity in agricultural lands. *Bot.Lett.*, *163*(4), 351–354, http://dx.doi.org/10.1080/23818107.2016.1236290.

Gao, Y., Duan, A.W., Qiu, X., Sun, J., Zhang, J., Liu, H. & Wang H. (2010). Distribution and Use Efficiency of Photosynthetically Active Radiation in Strip Intercropping of Maize and Soybean. *Agron J.*, *102*. 1149–1157.

Gao, Y., Wu, P., Zhao, X., & Wang, Z. (2014). Growth, yield, and nitrogen use in the wheat/maize intercropping system in an arid region of northwestern China. *Field Crop. Res*., *167*. 19–30. doi: 10.1016/j.fcr.2014.07.003

Ghaffarzadeh, M. (1999). Strip intercropping. *Iowa State University Extension, PM 176*, *3*(4).

Ghanbari, A. & Lee H.C. (2002). Intercropped field beans (*Vicia faba*) and wheat (*Tr.aestivum*) for whole crop forage: effect of nitrogen on forage yield and quality. *J. Agric. Sci.*, *138*. 311–314.

Ghanbari, A. & Lee H.C. (2003). Intercropped wheat (*Tr.aestivum* L.) and bean (*Vicia faba* L.) as a wholecrop forage: effect of harvest time on forage yield and quality. *Grass Forage Sci., 58*(1), 28–36.

Ghosh, P.K. (2004). Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semiarid tropics of India. *Field Crop Res*, *88*. 227–237.

Girjesh, G.K. & Patil, V.C. (1991). Weed management studies in groundnut and sunflower intercropping system. *J. Oilseeds Res*., *8*. 7–13.

Gitz, D.C, Xin, Z., Baker, J.T., Lascano, R.T., & Burke, J.J. (2015). Canopy light interception of a conventional and an erect leafed sorghum. *Am.J. Plant Sci., 6*. 2576–2884.

Gliessman, S.R. (1997). Agroecology: ecological processes in sustainable agriculture. Publisher: CRC Press.

Głowacka. I.E., Balzarini. J., & Wróblewski, A. E. (2013). The synthesis, antiviral, cytostatic and cytotoxic evaluation of a new series of acyclonucleotide analogues with a 1,2,3-triazole linker. *Eur.J.Med.Chem.*, 70, 703–722, http://dx.doi.org/10.1016/j.ejmech.2013.10.057.

Godfray, H. C. J, Beddington, J .R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, *327*. 812–818.

Gronle, A., Lux, G., Böhm, H., Schmidtke, K., Wild, M., Demmel, M., Brandhuber, R., Wilbois, K. P., Heß, J. (2015). Effect of ploughing depth and mechanical soil loading on soil physical properties weed infestation, yield performance and grain quality in sole and intercrops of pea and oat in organic farming. *Soil Tillage Res.*, *148*. 59–73.

Gutierrez, C. (1999). Evaluation of maize-chilli intercrop for the management of Anthonomus eugenii in Nicaragua. *Manejo Integrado de Plagas*, *54*. 73–77.

Guvenc, I. & Yildirim, E. (2006). Increasing Productivity with Intercropping Systems in Cabbage Production. *J. Sustain.Agric.*, *28*(4), 29–44.

Hauggaard-Nielsen, H., Mundus, S., & Jensen, E.S. (2012). Grass-clover undersowing affects nitrogen dynamics in a grain legume-cereal arable cropping system. *Field Crop Res., 136*. 23–31. https://doi.org/10.1016/j.fcr.2012.07.001

Hijbeek, R. (2017). On the role of soil organic matter for crop production in European arable farming. Thesis, 223, ISBN 978-94-6343-663-2, doi: https://doi.org/10.18174/421022.

Himanen, S.J., Saarnia, M., Lehtinen, H., Mäkinen, H., & Savikko, R. (2017). Intercropping can support ecological intensification in organic agriculture.*4th* *organic Conference: Organics for tomorrow's food systems, Mikkeli, Finland*, *13*(1), NJF Report, 65-66.

Hugar, H.Y. & Palled, Y.B. (2008). Effect of Intercropped Vegetables on Maize and Associated Weeds in Maize-Vegetable Intercropping Systems. *Karnataka J.Agric. Sci.*, *21*(2), 159–161.

Hummel, J.D. et al. (2009). Canola-Wheat intercrops for improved agronomic performance and integrated pest management. *Agr. J.*, *101*. 1190–1197.

Ijoyah, M.O, Iorlamen, T. & Idoko, G.A. (2012). Yield response of intercropped maize (*Zea Mais L.*) and okra (*Abelmoschus esculentus* (L.) Moench) to seasonal conditions at Makurdi in Nigeria. *J.Nat.Sci.Res., 2*(6), 79–86.

Iqbal, M. A., Bethune, B. J., Asif, I., Rana, N. A., Zubair, A., Haroon, Z. K. & Bilal, A. (2017). Agro-botanical response of forage sorghum-soybean intercropping systems under atypical spatio-temporal pattern. *Pak. J. Bot.*, *49*. 987–994.

Iqbal, M. A., Abdul, H., Imtiaz, H., Muzammil, H. S., Tanveer, A., Abdul, K., & Zahoor, A. (2018a). Competitive indices in cereal and legume mixtures in a South Asian environment. *J.Agron.*, *110*. 1–8.

Iqbal, M. A., Iqbal, A., Siddiqui, M. H., & Maqbool, Z. (2018b). Bio-agronomic evaluation of forage sorghum-legumes binary crops on Haplic Yermosol soil of Pakistan. *Pak.J. Bot.*, *50*. 1991–1997.

Iqbal, M.A., Hamid, A., Ahmad, T., Siddiqui, M. H., I. Hussain, S.Ali, A. Ali, & Z. Ahmad. (2019). Forage sorghum-legumes intercropping: effect on growth, yields, nutritional quality and economic returns, *Bragantia*, *78*(1), 82–95, doi: 10.1590/1678-4499.2017363.

Jaya, I.K.D., & Rosmilawati, S. (2017). Strip intercropping productivity of maize and pulse crops on a dryland. *ASSEHR*, vol. 98, *(ICPSUAS 2017)*

Jensen, J.R. (2003) Productivity in maize based cropping systems under various soil–water–nutrient management strategies in a semi-arid, alfisol environment in East Africa. *Agric. Water Manag.*, *59*. 217–237.

Jensen, E. S. (1996). Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops. *Plant Soil*, *182*. 25–38. doi: 10.1007/BF00010992.

Jones, G. A., & Sieving, K. E., (2006). Intercropping sunflower in organic vegetables to augment bird predators of arthropods. Agriculture, Ecosystems and Environment 117, 171–177, doi:10.1016/j.agee. 2006.03.026.

Jose, S., Gillespie, A.R., Seifert, J.R., Mengel, D.B., & Pope, P.E. (2000). Defining competition vectors in a temperate alley cropping system in the midwestern USA 3. Competition for nitrogen and litter decomposition dynamics. *Agrofor. Syst*., 61–77.

Jun-bo, D., Tian-fu, H., Jun-yi, G., Tai-wen, Y., Xin, S., Xiao-chun, W., Feng, Y., Jian,g L., Kai, S., Wei-guo, L., & Wen-yu, Y. (2018).Maize-soybean strip intercropping: Achieved a balance between high productivity and sustainability.*J. Integr.Agric., 17*(4), 747–754. https://doi.org/10.1016/S2095-3119(17)61789-1.

Juventia, S. D., Rossing, W. A., Ditzler, L., & Van Apeldoorn, D. F. (2021). Spatial and genetic crop diversity support ecosystem service delivery: a case of yield and biocontrol in Dutch organic cabbage production. *Field Crop Res.,* 261, doi: 10.1016/j.fcr.2020.108015.

Khatiwada, P. P. (2000). Intercropping cauliflower under maize: An approach to extend the cauliflower product in season for subsistence farmers. *Kasetsart J. Nat.Sci.*, *32*. 72–80.

Lawson, I.Y.D., Issahaku, A., Acheampong, S.K., Adams, B., & Tuffour, V. (2013) Time of planting and weed suppression abilities of some legumes intercropped with maize in the Guinea savanna zone of Ghana. *Agric. Biol.J. N. Am.*, *4*(4), 358–363.

Legwaila, G.M., Marokane, T.K. & Mojeremane, W. (2012). Effects of Intercropping on the Performance of Maize and Cowpeas in Botswana. *Int. J.Agric.Forestry*, *2*(6), 307–310.

Li, L., Sun, J., Zhang, F., Li, X., Yang, S., & Rengel, Z. (2001). Wheat/maize or wheat/soybean strip intercropping: I. Yield advantage and interspecific interactions on nutrients. *Field Crops Res.*, *71*. 123–137, https://doi.org/10.1016/S0378-4290(01)00156-3

Liang, K. M., Yang, T., Zhang, S. B., Zhang, J. E., Luo, M. Z., Fu, L., & Zhao, B. L. (2016). Effects of intercropping rice and water spinach on net yields and pest control: An experiment in southern China. *Int.J. Agric. Sustain.*, *14*. 448–465.

Liebman, M. & Dyck, E. (1993). Crop-rotation and intercropping strategies for weed management. *Ecol. Appl*., *3*(1), 92–122.

Lithourgidis, A.S., Dordas, C.A., Damalas, C.A., & Vlachostergios, D.N. (2011). Annual intercrops: an alternative pathway for sustainable agriculture. *Aust. J. Crop Sci*., *5*. 396–410.

Liu, S., Connor, J., Butler, J. R. A., Jaya, I. K .D., & Nikmatullah, A. (2016). Evaluating economic costs and benefits of climate resilient livelihood strategies. *Clim.Risk Manag., 12*. 115–129.

Liu, Y., Yin, H. J., Jiang, Y. R., Xue, M., Guo, C. Y., Shi, D. Z., et al. (2013). Correlation between Platelet Gelsolin and Platelet Activation Level in Acute Myocardial Infarction Rats and Intervention Effect of Effective Components of Chuanxiong Rhizome and Red Peony Root. *Evid. Based. Complement. Altern. Med.,* doi:10.1155/2013/985746

Lüscher, A., Mueller-Harvey, I., Soussana, J. F., Rees, R. M., & Peyraud, J. L. (2014). Potential of legume-based grassland–livestock systems in Europe: a review. *Grass Forage Sci.*, *69*. 206–228. doi: 10.1111/gfs.12124.

Ma, X. L., Wang, Y. J., Xie, S. L., Wang, C., & Wang, W. (2007). Glycinebetaine application ameliorates negative effects of drought stress in tobacco. *Russ.J.Plant Physiol., 54*. 472–479. doi: 10.1134/S1021443707040061.

MacLaren, C., Storkey, J., Menegat, A., Metcalfe, H., & Dehnen-Schmutz, K. (2020). An ecological future for weed science to sustain crop production and the environment. a review. *Agron. Sustain. Dev*., *40*. 24. doi: 10.1007/s13593-020-00631-6.

Martin, M.P.L.D. & Snaydon R.W. (1982). Intercropping barley and beans I. Effects of planting pattern. Experimental Agriculture, 18: 139–148.

Martin-Guay, M.O., Paquette, A., Dupras J., Rivest, D. (2018). The new Green Revolution: Sustainable intensification of agriculture by intercropping. *Sci.Total Environ., 615*. 767–772, doi: 10.1016/j.scitotenv.2017.10.024

Maurya, P., Lal, R. (1981). Effects of different mulch materials on soil properties and on the root growth and yield of maize (*Zea mays*) and cowpea (*Vigna unguiculata*). *Field Crops Res., 4*. 33–45.

Mazaheri, D., Madani, A. & Oveysi, M. (2006). Assessing the land equivalent ratio (LER) of two corn (*Zea mays* L.) varieties intercropping at various nitrogen levels in Karaj, Iran. *JCEA*, *7*(2), 359–364.

Mehta, R. S., Meena, S. S., & Lal, G. (2017). Effect of intercropping seed spices with vegetable for enhancing system profitability. *Int.J. Seed Spices, 7*(2)*,* 33–39.

Mei, P. P, Gui, L.G, Wang, P, Huang, J. C, Long, H. Y, Christie, P., & Li, L. (2012). Maize/faba bean intercropping with rhizobia inoculation enhances productivity and recovery of fertilizer P in a reclaimed desert soil. *Field Crops Res.*, *130*. 19–27.

Mobasser, H.R., Vazirimehr, M.R. & Rigi, K. (2014). Effect of Intercropping on Resources use, Weed Management and Forage Quality. *Int.J.Plant Animal Env. Sci.*, *4*(2), 706–713.

Mousavi, S.R., & Eskandari, H. (2011). A General Overview on Intercropping and Its Advantages in Sustainable Agriculture. *J. Appl. Environ. Biol. Sci.*, *1*(11), 482–486.

Mucheru-Muna, M., Pypers, P., Mugendi, D., Kungu J., Mugwe, J., Merckx R., & Vanlauwe, B. (2010). Staggered Maize-Legume Intercrop Arrangement Robustly Increases Crop Yields and Economic Returns in the Highlands of Central Kenya. *Field Crops Res.*, *115*. 132–139.

Muoneke, C.O., Ogwuche, M.A.O., & Kalu, B.A. (2007). Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savannah agroecosystem. *Afr. J. Agr. Res., 2*. 667–677.

Nampala, P., Ogenga-Latigo, M.W., Kyamanywa, S., Adipala, E., Oyobo, N., & Jackai, L.E.N. (2002). Potential Impact of Intercropping on Major Cowpea Field Pests in Uganda. *Afr. Crop Sci. J., 10*(4), 335–344.

Nasar, J., Alam, A., Nasar, A., & Khan, M. Z. (2019). Intercropping Induce Changes in Above and Below Ground Plant Compartments in Mixed Cropping System. *Biomed J. Sci. Tech. Res.*, *17*(5), 1–8, doi: 10.26717/BJSTR.2019.17.003054.

Nentwig, W. (1998). Weedy plant species and their beneficial arthropods: potential for manipulation in field crops. In: Pickett,C.H. and R.L.Bugg (eds.) Enhancing Biological Control: habitat management to promote natural enemies of agricultural pests. *University of Califomia Press, Los Angeles*, 49– 84.

Nishanthi, S., Brintha, N. K. K, & Sutharsan S., (2015). Study on Black gram (Vigna mungo)/vegetable Amaranthus (*Amaranthus tricolor* L.) *Intercropping in sandy regosol.IntSym, SEUSL*

Nowatzki, J., Endres, G., & Dejong-hughes, J. (2017). Strip till for field crop production. *North Dakota State University Extension Service and University of Minnesota Extension, 1–8.*

Odhiambo, GD, & Ariga, ES. (2001). Effect of intercropping maize and beans on striga incidence and grain yield *7th Eastern and Southern Africa Regional Maize Conference, 183–186.*

Ofori, F. & Stern, W.R. (1987). Cereal-legume intercropping system. *Adv.Agron.*, *41*. 41–90.

Ofosu-Anim, J. & Limbani, N. V. (2007). Effect of intercropping on the growth and yield of cucumber (*Cucumis sativus* L.) and okra (*Abelmoschus esculentus* L. Moench). *Int. J.Agric.Biol., 4*. 594–597.

Pingali, P.L. (2012). Green revolution: impacts, limits, and the path ahead. *Proc. Natl. Acad. Sci.* U. S. A. *109*. 12302–12308.

Pino, M., De-Los, A., Domini, M.E., Terry, E., Bertoli, M., et al. (1993) Maize as a protective crop for tomato in conditions of environmental stress. *Cultivos Tropicales*, *15*. 60–63.

Pretty, J., & Bharucha, Z.P. (2014). Sustainable intensification in agricultural systems. *Annals of Botany*, 1-26, doi:10.1093/aob/mcu205

Qian, X., Zang, H., Xu, H., Hu, Y., Ren, C., Guo, L., Wang, C., & Zeng, Z. (2018). Relay strip intercropping of oat with maize, sunflower and mung bean in semi-arid regions of Northeast China: Yield advantages and economic benefits. *Field Crops Res.,* 223, 33–40. https://doi.org/10.1016/j.fcr.2018.04.004

Rao, M., & Mathuva, M. (2000). Legumes for improving maize yields and income in semi-arid Kenya. *Agric. Ecosyst. Environ.*, *78*(2), 123–137.

Rao, M. R. & Singh, M. (1990). Productivity and risk evaluation in contrasting intercropping system. *Field Crop Res.*, *23*. 279–293.

Raza, M. A., Gul, H., Wang, J., Yasin, H.S., Qin, R., Khalid, M.H. B., Naeem, M., Feng, L.Y., Iqbal, N., Gitari, H., Ahmad, S., Battaglia, M., Ansar, M., Yang, F., & Yang, W. (2021). Land productivity and water use efficiency of maize-soybean strip intercropping systems in semi-arid areas: A case study in Punjab Province, Pakistan. *J. Clean. Prod.*, *308*. 1–10, 127282.

Reda, F., Verkleij, J. A. C., & Ernst, W. H. O. (2005). Relay cropping of sorghum and legume shrubs for crop yield improvement and Striga control in the subsistence agriculture region of Tigray (Northern Ethiopia). *J. Agron.Crop Sci.*, *191*. 20–26. https://doi.org/10.1111/j.1439-037X.2004.00126.x

Ren, L. et al. (2008). Intercropping with aerobic rice suppresed Fusarium wilt in watermelon. *Soil Biol Biochem, 40*. 834–844.

Rodriguez, C., Mårtensson, L.M.D, Jensen, E. S., & Carlsson, G. (2021). Combining crop diversification practices can benefit cereal production in temperate climates. *Agron. Sust. Dev.*, 41, 48, https://doi.org/10.1007/s13593-021-00703-1/.

Sarkar, B., Patra, A., & Purakayastha, T., (2008). Transgenic Bt-cotton affects enzyme activity and nutrient availability in a sub-tropical inceptisol. *J. Agron. Crop Sci.*, *194*. 289–296.

Schulz, V.S., Schumann, C., Weisenburger, S., Müller-Lindenlauf, M., Stolzenburg, K., & Möller, K. (2020). Row-Intercropping Maize (*Zea mays* L.) with Biodiversity-Enhancing Flowering-Partners-Effect on Plant Growth, Silage Yield, and Composition of Harvest Material. *Agriculture*, *10*. 524.

Seran, T.H. & Brintha, I. (2010). Review on Maize Based Intercropping. *J. Agron., 9.* 135–145.

Šeremešić, S., Vojnov, B., Manojlović, M., Milošev, D., Ugrenović, V., Filipović, V., & Babec, B. (2017). Organska poljoprivreda u službi biodiverziteta i zdravlja. *Letopis naučnih radova. Poljoprivredni fakultet, Novi Sad*., *41*(2), 51–60.

Šeremešić, S., Manojlović, M., Tomšik, M., Vujić, N., Jaćimović, G., & Vojnov, B. (2018). Linking mulch application and fertilization with organic soybean and buckwheat production. *6th Int. Conf. Org. Agric. Sci. ICOAS. 7-9 November. Eisenstadt, Austria.* 44.

Šeremešić S., Manojlović M., Tomšik M., Vujić N., Đurđević B., Dolijanović Ž., Vojnov B., & Babec B. (2020). The effects of mulch and bio-fertilizers on soil properties in organic soybean and buckwheat production. *Ith Int. sci. professional conference. Original Scientific Paper*, 122–130.

Silwana, T.T., & Lucas, E. (2002). The effect of planting combinations and weeding on the growth and yield of component crops of maize/bean and maize/pumpkin intercrops. *J. Agric. Sci., 138*. 193–200.

Singh, S.N. & Kumar, A. (2002). Production potential and economics of winter maize based intercropping systems. *Ann. Agric. Res.*, *23*(4), 532–534.

Singh, J., Abhilash, P.C., & Gupta, V.K. (2016). Agriculturally important microbes in sustainable food production. *Trend Biotechnol*., *34*. 773–775.

Singh, J., Abraham, T., Kumar, M., & Choudhary, A. (2018). Influence of different cultural method and potassium levels for improvement of growth & yield of wheat under Eastern U.P. Green Farming. 4, 638–640.

Singh, P., Boote, K.J., Yogeswara Rao, A., Iruthayaraj, M.R., Sheikh, A.M., Hundal, S.S., Narang, R.S., & Singh, P. (1994). Evaluation of the groundnut model PNUTGRO for crop response to water availability, sowing dates, and seasons. *Field Crops Res*., *39*. 147–162.

Soria, J. et al. (1975). Investigación sobre sistemas de producción agrícola para el pequeño agricultor del trópico, Turrialba 25, 213–338.

Sullivan, P. (2001). Intercropping Principles and Production Practices. Appropriate Technology Transfer for Rural Areas (ATTRA), USDA Rural Business

Tignegre, J.B.S., Larbi, A., Tenkouano, A., Nurudeen, A., Asante, M., Boateng, R., Rouamba, A., Sobgui, M.C., & Chagomoka T. (2018). Optimization of Maize-Vegetable (African Eggplant and Pepper) Intercrops in Northern, Upper West and Upper East Regions of Ghana. *JOJ Hortic Arboric, 1*(2), 0029–0034.

Tilman, D., Balzer, C., Hill, J. & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture *Proc. Natl Acad. Sci.*, *108*. 20260–4.

Tsubo, M., Walker, S., & Ogindo, H.O.A. (2005). Simulation model of cereal-legume intercropping systems for semi-arid regions. I. Model application. *Field Crop Res.*, *93*(1), 23–33.

Ugrinović, M., Mijatovic, M., Zdravković, J., Girek, Z., Kuzmanovic, D., Rasulic, N., & Josic, D. (2014). Intercropped red beet and radish with green bean affected microbial communities and nodulation by indigenous rhizobia. *Agric. Food Sci., 23*. 173–185.

Upadhyaya, R., Patiram, C., & Ray, S. (1994). Decline status of mandarin orange (*Citrus reticulata Blanco*) in Sikkim. *J. Hill Res.*, *7*(2), 83–88.

Vandermeer, J.H. (1989). The ecology of intercropping. Cambridge, UK: Cambridge University Press

Vandermeer, J. (1990). Intercropping. 481-516.

Vandermeer, J.H., (1992). The Ecology of Intercropping. Cambridge University Press.

Wang, G.L., Chen, X.P., Cui, Z.L., Yue, S.C., & Zhang, F.S. (2014). Estimated reactive nitrogen losses for intensive maize production in China. *Agric. Ecosyst. Environ.*, *197*. 293–300.

Wang, Y., Wang, M.L., Sun, Y.L., Wang, Y.T., Li, T.T., Chai, G.Q., Jiang, W., Shan, L., Li, C., Xiao, E. & Wang, Z. (2015). FAR5, a fatty acylcoenzyme a reductase, is involved in primary alcohol biosynthesis of the leaf blade cuticular wax in wheat (*Tr.aestivum* L.). *J. Exp. Bot*., *66*. 1165–1178.

Werf Van der, H., Knudsen, M.T., & Cederberg, C. (2020). Towards better representation of organic agriculture in life cycle assessment. Nature Sustainability, Springer Nature, *3*(6), 419–425. ff10.1038/s41893-020-0489-6

Wu, K. (2012). Above-and below-ground interspecific interaction in intercropped maize and potato: A field study using the 'target'technique. *Field Crops Res., 139*. 63–70.

Wu, Yu-shan, Yang, F., Gong, Wan-zhuo, Shoaib, A., Fan, Yuan-fang, Wu, Xiao-ling, Yong, Tai-wen, Liu, Wei-guo, Shu, K., Liu, J., Du, Jun-bo, & Yang, Wen-yu. (2017). Shade adaptive response and yield analysis of different soybean genotypes in relay intercropping systems. *J. Integr. Agric.*, *16*(6), 1331–1340.

Yildirim, E., & Ekinci, M. (2017). Intercropping Systems in Sustainable Agriculture. *Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi, 12*(1), 100–110, ISSN 1304-9984

Zhang, F., & Li, L. (2003). Using competitive and facilitative interactions in intercropping systems

enhances crop productivity and nutrient-use efficiency. *Plant and Soil*, *248*. 305–312.
Zhang, G. G., Zhang, C. Y., Yang, Z. B., & Dong, S. T. (2013). Root distribution and N acquisition in an alfalfa and corn intercropping system. *J. Agric. Sci.*, *5*. 128–142.
Zhang, F., Wenxue, Li., & Long, Li. (2003). Do interspecific interactions reduce phosphorous fertilizer rates in the faba bean/maize intercropping. *In Proceedings:2nd Int. Symp.phosphorous dynamics in the soil plant continuum*, *26*(3), 21–26.
Zhang, G., Yang, Z. & Dong, S. (2011). Interspecific competitiveness affects the total biomass yield in an alfalfa and corn intercropping system. *Field Crops Res.*, *124*. 66–73. https://doi.org/10.1016/j.fcr.2011.06.006.
Zhang, F. (2004). An overview of rhizosphere processes related with plant nutrition in major cropping systems in China. *Plant and Soil*, *260*(1-2), 89–99.
Zougmoré, R., Kambou, N.F., Ouattara, K., & Guillobez, S. (2001). Sorghum-cowpea intercropping: an effective technique against runoff and soil erosion in the Sahel (Saria, Burkina Faso). *Arid Soil Res. Rehab., 14*(4), 329–342.