Scientific Papers. Series B, Horticulture. Vol. LXVI, No. 1, 2022
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

REVIEW ON THE POSITIVE INFLUENCE OF INTERCROPPING SYSTEMS FOR ORGANIC VEGETABLE GROWING

Dan-Ioan AVASILOAIEI, Mariana CALARA, Mihaela-Carmina BENCHEA, Tina Oana CRISTEA

Vegetable Research and Development Station Bacau, 220 Calea Bârladului Street, Bacău, Romania

Corresponding author email: avasiloaiei_dan_ioan@yahoo.com

Abstract

Intercropping is considered to be a fundamental tool for ensuring agricultural sustainability and productivity, a matter of major importance in the specific context of the last decades and, mainly, the last two years.
Within European agriculture, conventional advantages of intercropping system following laborious experiments were disregarded by farmers because of the justified goal of maximizig profits using affordable pesticides on the market. This determines farmers to focus on increasing the size of their farms, replacing manual labor with a mechanized one, resulting a technological specialization of a few crops at the expense of biodiversity.
However, nowadays, following the Covid-19 pandemic and the entire chain of effects it generated, agriculture was directly affected due to the limitation of worldwide transport amplitude and the scarcity of products and raw materials that arose, the price for some of them becoming trully prohibitive (to be seen the case of chemical fertilizers at the end of year 2021).
The present paper aims to highligh some paramount matters of using intercropping systems in vegetable crop practice, regarding the perspective of soil, environment, ecosystem biodiversity and economical sustainability.

Key words*: intercropping, organic farming, environmental sustainability, GHG emissions, cover crops.*

INTRODUCTION

Probably never before in the history of mankind emerged the need of revolutionizing the way we practice agriculture, adopting a new perspective in contrast with the conventional one, which is based on an impressive number of inputs, intensely promoted after the Second World War, alongside the far advertised "Green Revolution". Nowadays, on the background of increasing climate changes, it becomes imperative to find solutions to minimize the impact that agriculture has on the environment. One cannot argue about sustainability in the true sense of the word from an environmental point of view if we refer strictly to the management of intensive farming systems because the enhancement of agriculture has, among other things, several unfavorable effects, such as: soil erosion, decreased biodiversity, nutrient loss and reduced soil fertility (Islam et al., 2016, cited by Diacono et al., 2021).

Therefore, the environmental challenges attributed to agriculture are primarily related to the reduction of soil, water and air quality, which are often resulting from the application of inappropriate nutrient management strategies. Farmers are typically using intensive chemicalization practices to maintain soil productivity, alongside management, which reduces organic soil matter (SOM) and at the same time increases erosion, acidification and salinisation (Dumanski et al., 1986, cited by Chapagain and Riseman, 2014).

Organic agriculture becomes more relevant than ever, the example in this respect being the policies adopted at the European Community level, which aims that 25% of all agricultural operations should respect the rigors of this type of agriculture by 2030.

One of the main aspects that ensures the sustainability of organic farming is related to the judicious use of land. If we refer strictly to plant production, this goal is mainly achieved by adopting intercropping systems. According to Vandermeer (1989), they involve "the cultivation of two or more plant species in a way that enables them interact agronomically". Intercropping is considered to be a fundamental means of ensuring agricultural sustainability and productivity (Brooker et al., 2015). Regarding organic vegetable production, Shanmugam et al., (2021) shows that intercropping systems can improve both yield and the efficiency of the nitrogen use by mixing complementary species in terms of resource use. Overall, the benefits identified from intercropping two or more plant species include higher productivity and high profitability per unit area (Yildirim and Guvence, 2005), improved soil fertility by nitrogen fixing (Hauggaard-Nielsen et al., 2001, 2009), increased resource efficiency (Knudsen et al., 2004), limited damage caused by disease and pest attack (Banik et al., 2006; Sekamatte et al., 2003), improved fodder quality (Bingol et al., 2007; Ross et al., 2004), as well as improving the carbon and nitrogen dynamics (Oelbermann and Echarte, 2011; Dyer et al., 2012).

MATERIALS AND METHODS

Data source and selection criteria

Data have been collected from an impressive number of scientific studies, mostly up-to-date, especially from the last 15 years. However, given the importance of the topic and the relevance of the studies conducted by the promoters of this vegetable growing system in the second half of the last century, some of the results of their research were briefly presented.

The main advantages of adopting the intercropping system for vegetable growing have been identified, classified and rated.

The database from Google Academic, ScienceDirect, Springer.com has been reviewed using keywords such as "intercropping", "organic farming", "environmental and soil sustainability".

A number of 397 scientific papers were identified that we considered to be paramount and, consequently, were analyzed.

The studies selected for this synthesis met the following criteria: 1. many of them are relatively recent and, as such, the conclusions drawn may be immediately applicable; 2. they present in detail the advantages of using the intercropping system in organic farming; 3. the results drawn from researches are relevant or based on a sufficient number of scientific papers.

RESULTS AND DISCUSSIONS

Intercropping implies the cultivation of two or more species simultaneously, on the same area of land, during a growing season (Ofori and Stern, 1987) and is considered to be an important strategy in the development of sustainable production systems, especially those aimed at limiting the use of raw materials of an external nature (Adesogan et al., 2002).

Embracing these organic farming practices increases the diversity and complexity of the agro-ecosystem, providing it long-term sustainability (Montemurro et al., 2018; Altieri and Koohafkan, 2013).

The use of agri-environmental practices also enhances the ability (sometimes called adaptive capacity) of a system to take over any disturbances without qualitatively altering the fundamental interactions that characterize it, and this ability can be defined as system resilience (Kaye and Quemada, 2017).

The role of intercropping on the rational use of land

Schröder and Köpke (2012) reiterated the positive value of the nitrogen land use rate in the case of intercropping broad bean and oilseeds (eg saffron and mustard) regardless of the type of soil they were grown in.

Intercropping barley and pea highlighted a number of real benefits, including higher land productivity (12-32% higher compared to the variant where barley was cultivated as a monoculture), an increased quality of biomass (high content of nitrogen and protein), a significant accumulation of carbon and nitrogen in the biomass of the soil surface, as well as a higher net exchange of CO_2 and a gross rate of photosynthesis within ecosystem. However, the significance of using the intercropping system has varied greatly depending on the growing conditions and the proportion of species that have been used (Hauggaard-Nielsen et al., 2009; Jensen, 1996; Lauk and Lauk, 2008).

The agronomic parameters used to compare the yields of intercropping and monocropping systems are the land equivalent ratio (LER) (Mead & Willey, 1980) and the relative value total (RVT) (De Wit and van den Bergh, 1965; Schultz et al., 1982).

The land equivalent ratio represents the proportion of land needed to produce a certain amount of yield in the monoculture system as opposed to the intercropping system.

Overall, studies on the use of intercropping provide a conclusive reason to investigate the association between brassicas - pulses, given their potential to use less land in order to supply the same productive yield as monocultures (Shanmugam et al., 2021).

Relating intercropping with greenhouse gases (GHG)

In recent studies, both energy and carbon footprint analyzes have been used to determine crop production efficiency (Pratibha et al., 2015; Ozalp et al., 2018) and the sustainability of different soil fertilizer regimes (Pergola et al., 2018; Guardia et al., 2019).

Assessment of the carbon footprint is an important feature in rating the impact of a production system on global warming / climate change (Wiedmann and Minx, 2007). The higher the yield of crops, the lower the carbon footprint per kilogram (Pishgar-Komleh et al., 2017).

Worldwide, previous studies have demonstrated the impact of vegetable cultivation on global warming due to high emissions caused by energy consumption, agricultural works, use of fertilizers or irrigation (Torrellas et al., 2012; Khoshnevisan et al., 2014; Plawecki et al., 2014; Bartzas et al., 2015; Clavreul et al., 2017; Ntinas et al., 2017; Zarei et al., 2019).

The main greenhouse gases resulting from mismanagement of agricultural practices are carbon dioxide, methane and nitrogen oxide (IPCC, 2007).

The resulting carbon footprint of producing 1 kilogram of vegetables in the intercropping system is about one-fifth compared with monoculture, which highlights the importance of intercropping in terms of GHG mitigation and, consequently, environmental impact.

De Jesus Pereira et al. (2020) showed that greenhouse gas emissions were higher in the case of monoculture vegetable systems (25,273 kg CO_2 eq/ha), compared to the ones where intercropping has been chosen (16,368 kg CO_2 eq/ha).

In terms of soil carbon stock, the intercropping system emitted less CO_2 into the atmosphere (690 kg CO2 eq/ha) compared to the monocropping system (1,380 kg CO_2 eq/ha) over a twenty-year period, due to the fact that the area used in the case of the intercropping was smaller.

Several studies (Chirinda et al., 2010; Hwang et al., 2017) have shown that when nitrogen availability was increased, more N_2O was produced by nitrification and denitrification processes due to the proliferation of microorganisms. However, a number of researchers have reported that the use of agro-ecological crops can reduce N2O emissions compared to systems without cover crops by increasing the consumption of nitrogen of the so called “catch crop”, especially if non-pulses crops are used (Muhammad et al., 2019).

Effects of using the intercropping system in relieving salinization phenomena and nitrate accumulations of soil levels

Some previous studies have found that the stress caused by increased salinity could be alleviated by intercropping cash crops with some plant species capable of removing this excess (Aksoy et al., 2003).

Turfgrass represents a category of plant species with a higher tolerance to salinity because they had to adapt and survive into soils with a high degree of salinity during their phylogenetic development or to be irrigated with recycled / sewage water with a high salt content (Huang et al., 2014). Consequently, most turfgrass species are an excellent companion for the main horticultural crops, in order to alleviate the stress caused by the high salinity of the soils.

Turfgrasses constitutes the category of soil-covering plants, having a fibrous root system which are being distributed in the upper layer of soil, in the first 10 cm (Lyons et al., 2011). In contrast, most vegetables belong to the category of plants with a pivoting root system, with an overwhelming proportion of roots in the lower layer of the soil, up to a depth of 80 cm (Thorup-Kristensen and van den Boogaard, 1998; Vansteenkiste and et al., 2014).

Intercropping different species of turfgrasses with high-value vegetable crops is mainly based on the assumption that shallow rooting of turfgrass species does not lead to competition for nutrients *per se* but, on the contrary, could absorb salt ions that have accumulated on the soil surface and eliminate their negative effects into the vegetable production system (Hu et. al., 2020).

The degree of salinity tolerance and also salt absorption may vary depending on the species and varieties of turfgrass (Chavarria et al., 2019; Soliman et al., 2018; Uddin et al., 2012). Some Bermuda grass varieties (*Cynodon* spp.) have been shown to be tolerant to a degree of salinity between 50-200 mM NaCl, without adversely affecting plant growth (Hu et al., 2012). Dong et al. (2019) showed that some species of turfgrass could excel in accumulating a higher amount of salt ions and heavy metals. Xia et al. (2019) highlighted the beneficial effect of intercropping with alfalfa *(Medicago sativa)* in inhibiting soil alkalization and salinization and improving its quality. Simpson et al. (2018) found that the association with purslane (*Portulaca oleracea*) could alleviate the salinity stress and could increase the productive yield and quality of watermelon fruits (*Cucumis melo*). Kilic et al. (2008) outlined a decrease in soil salt level and the elimination of the stress caused by it in an orchard where an intercropping system with purslane (*Portulaca oleracea*) was chosen.

About 80% of the amount of nitrates to which humans are exposed comes from vegetables (Rathod et al., 2016). Nitrates themselves are relatively harmless, but they have the ability to be reduced quite easily to nitrites, which can then be converted to nitrosamines, considered to have carcinogenic potential (Lundberg et al., 2008).

Therefore, the amount of nitrites and nitrates in vegetable products should be minimized in order to ensure a qualitatively safe vegetable production (Kalaycioglu and Erim, 2019). Nitrates can be absorbed directly by the roots of plants and can be transported to other organs through the nitrogen nutrition phenomenon (Wang et al., 2018). In plants, nitrates can be reduced to nitrites and further to ammonia by nitrogen reductase that occurs in plastids. Ammonia can be further assimilated in order to form amino acids through the synthesis of glutamine and glutamate (Coskun et al., 2017). Nitrate accumulation in vegetables is mainly correlated with nitrate soil level (Marousek et al., 2017).

It has been found that the use of green manure in intercropping systems reduces the risk of nitrate leaching both in the conventional system (Manevski et al., 2015; Mariotti et al., 2015) and also in the organic growing of cereals and vegetables (Whitmore and Schröder, 2007). Thorup-Kristensen et al., 2012).

Regarding the nitrate content, Hu et al. (2020) have shown that intercropping cauliflower with different species of turfgrass had a significant impact on it, both in the soil and in the rhizosphere area of cauliflower, compared to the control variant, as follows: 73.3% and 60.1% in the case of *Paspalum vaginatum,* 68.9% and 52.7%, at *Eremochloa ophiuroidesde*, succeeded by *Festuca arundinacea* (67.4% and 49%) and *Cynodon dactylon* (65% and 44%). The lowest impact was recorded in the cauliflower - Kentucky bluegrass (*Poa pratensis*) association, both in the rhizosphere and in soil, with 30.7% and, respectively, 35.7%. Intercropping cauliflower with *Paspalum vaginatum* and *Eremochloa ophiuroides* also significantly reduced the nitrate content of young cauliflower shoots by 46.4% and 29%, compared to the control variant.

Hu et al. (2020) presents the current methods of mitigating the problems related to soil salinization and nitrate accumulation of the vegetable growing systems: i) use of water (from rainfall or irrigation) to remove salts accumulated in the soil surface layer (Du et al., 2019; Zhang et al., 2020); (ii) rational fertilization management programs to reduce the accumulation of soil salts (Machado and Serralheiro, 2017); (iii) applying amendments in order to absorb soil salts and reduce stress on vegetable crops (Fan et al., 2016).

The influence of intercropping on crop yields

In organic vegetable growing, adopting the intercropping system can improve both the yield and the efficiency of nitrogen use, by associating complementary species regarding the use of resources (Shanmugam et al., 2021). When two vegetable species are intercropped, the dominant ones can increase both their productive yield and nutrient uptake (Zhang & Li, 2003), while the production of the other crop is reduced due to interspecific competition for nutrients.

The beneficial effect on the yield in the case of the intercropping system is shown in Table 1.

Table 1. List of some intercropping types and their benefits on vegetable and non vegetable crop yields

Intercropped species	The type of beneficial effect on yield	Author
Faba bean (*Vicia faba* L.) – White mustard (*Sinapis alba)* and cabbage *(Brassica oleracea* L. var. *capitata*)	- Higher yields for the Brassicaceae crops	(Schröder & Köpke, 2012; Lepse et al., 2017; Shanmugam et al., 2021)
Faba bean (*Vicia faba* L.) – Garlic (*Allium sativum* L.)	- Nitrogen transfer to the cash crop	(Tang et al., 2018; Thilakarathna et al., 2016)
Pea *(Pisum sativum L.)* – Wheat (*Triticum aestivum*) / Barley *(Hordeum vulgare)*	- Higher yields; - Improvement of grain and fodder quality	(Hauggaard-Nielsen et al., 2009; Carr et al., 2004; Lauk and Lauk, 2008)
Cucumbers (*Cucumis sativus* L.*)* – Lettuce (*Lactuca sativa* L.)	- Higher yields	(Rezende et al*.,* 2010)
Tomatoes (*Solanum lycopersicum L.*) – Lettuce (*Lactuca sativa* L.)	- Higher yields	(Cecílio Filho et al*.,* 2011)
Cauliflower (*Brassica oleracea* var. *Botrytis)* – *Paspalum vaginatum/Festuca arundinacea*	- Higher yields	(Hu et al., 2020)
Leek *(Allium porum L.)* – White clover (*Trifolium repens*)	- Higher yields when clover was sowed after leek planting	(Kolota and Adamczewski-Sowinska, 2004; den Hollander et al., 2007)
Leek *(Allium porum L.)* – Ryegrass (*Lolium spp.)*	- Higher yields when ryegrass was sowed six weeks after leek planting	(Müller-Schärer, 1996)
Maze (*Zea mays* L.) – Green manures spp.	- Increase of the dry matter content in corn grains	(Uchino et al*.,* 2009)
Tomates (*Solanum lycopersicum L.*) – Italian clover *(Trifolium incarnatum)*	- Higher yields for the cash crop	(Diacono et al*.*, 2021)
Cabbage (*Brassica oleracea* L. var. *capitata*) – Chilli peppers *(Capsicum annuum* L.*)*	- Higher yields	(Leong and Zaharah, 1991)
Pulses – Grains	- Higher yields for cereals when legumes are used as green manures	(Bedoussac and Justies, 2010; Bedoussac et al., 2015)
Broccoli (*Brassica oleracea* var. *italica)* – Beans (*Phaseolus vulgaris* L.) / Potatoes *(Solanum tuberosum* L.*)*	- Higher yields	(Santos et al., 2002)
Cabbage (*Brassica oleracea* L. var. *capitata*) – Romaine type lettuce (*Lactuca sativa* L. var. *longifoila*), / Leaf lettuce (*L. sativa* L. var. *crispa*) / Onion (*Allium cepa* L.) / dwarf bean (*Phaseolus vulgaris* L. var. *nanus*)	- Optimizes both yield and profitability	(Guvenc and Yildirim, 2006)
Faba bean (*Vicia faba* L.) - Wheat (*Triticum aestivum* L.)	- The growth and yield of cereal crop increased by 19% -28% and, respectively, 20% - 28%	(Xiao et al., 2018).

The impact of intercropping system on diseases and pests control

Over the past decades, studying the intercropping system effects on diseases and pests has favored the accumulation of a considerable number of bibliographic data. The general effects of using intercropping system in vegetable production are linked to the suppression of most pest and disease populations (Theunissen, 1994b).

Some of the intercropping scheme on which research has been conducted in terms of diseases and pests control are presented in Tables 2 and 3.

Table 2. List of some intercropping types and their benefits on vegetable pest control

Intercropped species	Insect population assessment	Author
Bean (*Phaseolus vulgaris* L.) – winter wheat (*Triticum aestivum* L.)	- *Empoasca fabae, Lygus lineolaris, Aphis fabae, Systena frontalis*	(Tingey and Lamont, 1988)
Brussels sprouts (*Brassica oleracea* var. *gemmifera*) – *Spergula arvensis*	- *Mamestra brassicae, Evergestis forficalis, Brevicoryne brassicae*	(Theunissen and Den Ouden, 1980)
Brussels sprouts (*Brassica oleracea* var. *gemmifera*) – Tomatoes *(Solanum lycopersicum* L.*)*	- *Phylotreta cruciferae, Plutella xylostella, Aleyrodes brassicae*	(Tahvanainen and Root, 1972; Philips, 1977)
Cabbage (*Brassica oleracea* L. var. *capitata*) – Tomatoes *(Solanum lycopersicum* L.*)*	- *Plutella xylostella*	(Burandy and Raros,1975)
Beans (*Phaseolus vulgaris* L.) – Grass weeds (*Eleusine* and / *Leptochloa*)	- *Empoasca kraemeri*	(Altieri et al.,1977)
Cabbage (*Brassica oleracea* L. var. *capitata*) – Living mulches (*Agrostis stolonifera, Festuca rubra, Poa pratensis, Trifolium repens)*	- *Phylotreta cruciferae Brevicoryne brassicae*	(Andow et al., 1986)
Cabbage (*Brassica oleracea* L. var. *capitata*) – Beans (*Phaseolus vulgaris* L.)	- *Delia radicum, Delia floralis*	(Hofsvang, 1991)
Cabbage (*Brassica oleracea* L. var. *capitata*) – *Trifolium* spp. (*T. repens, T. subterraneum*)	- *Mamestra brassicae, Brevicoryne brassicae Delia brassicae*	(Theunissen et al*.,* 1995)
Carrot (*Daucus carota*) – Onion *(Allium cepa* L.*)*	- *Psila rosae* (carrot), *Thrips tabaci* (Onion), *Cavariella aegopodii*	(Uvah and Coaker*,* 1984)
Leek *(Allium porum L.) – Trifolium subterraneum*	- *Thrips tabaci*	(Theunissen and Schelling, 1993)

Table 3. List of some intercropping types and their benefits on vegetable disease control

Intercropped species	Disease assessment	Author
Leek *(Allium porum* L.*) – Trifolium subterraneum*	- *Puccinia allii*	(Theunissen et al*.,* 1996)
Barley (*Hordeum vulgare*) – Pea (*Pisum sativum*), Lupin (*Lupinus* L.), Faba bean (*Vicia faba*)	- *Pyrenophora teres, Puccinia hordei*	(Hauggaard-Nielsen et al., 2008)
Wheat (*Triticum aestivum* L.) - Faba bean (*Vicia faba*)	- Wheat powderly mildeaw	(Chen et al., 2007)
Barley (*Hordeum vulgare*) – Wheat (*Triticum aestivum* L.)	- Seed head disease	(Naudin et al., 2009)
Barley (*Hordeum vulgare*) – Lupin (*Lupinus* L.)	- *Pleiochaeta setosa*	(Hauggaard-Nielsen et al., 2008)
Tomatoes (*Solanum lycopersicum* L.) – Kale (*Brassica oleracea* L. var. *acephala)*, Onion (*Allium cepa* L.)	- *Tomato spotted wilt virus (TSWV)*	(Ramkat et al., 2008)
Potato *(Solanum tuberosum* L.*)* - Grass-Clover	- *Phytophtora infestans*	(Bouws and Finckh, 2008)
Potato *(Solanum tuberosum* L.*)* - Faba bean (*Vicia faba*)	- *Phytophtora infestans*	(Garrett et al., 2001)
Cabbage (*Brassica oleracea* L. var. *capitata*) – Garlic *(Allium sativum* L.*)*	- *Sclerotium cepivorum*	(Zewde et al., 2007)
Tomatoes (*Solanum lycopersicum* L.) – Cucumbers (*Cucumis sativus* L.*)*	- Yellow leaf curl	(Al-Musa, 1982)
Tomatoes (*Solanum lycopersicum* L.) – Cowpea (*Vigna unguiculata* L.)	- *Pseudomonas solana-cearum*	(Michel et al., 1997)
Chilli peppers (*Capsicum annuum*) – Maize (*Zea mays* L.)	- *Phytophtora capsici*	(Sun et al., 2006; Zu et al., 2008)
Watermelon (*Citrullus lanatus)* – Rice (*Oryza sativa*)	- *Fusarium oxysporum*	(Su et al., 2008)

Some effects of the intercropping system on weed management

The intercropping system can represent a technological link in weed suppression, although the results obtained so far are variable (Vandermeer, 1989, Stefan et al., 2021). The positive effects on weed suppression have been shown in a wide range of crops, including maize, rye, soybeans, zucchini, summer cabbage, dwarf beans and tomatoes (Ilnicky & Enache, 1992). Furthermore, some clover species such as *Trifolium repens, T. pratense*, *T. fragiferum* and *T. dubium* turned out to be suitable for use in combination with a main crop / cash crop for the same purpose. If the crops are set up on rows, mowing the secondary associated crop can represent a suitable way to prevent tall weeds from flowering and seeding.

When the role of intercropping is to suppress weeds, its effects are expressed according to the savings made in terms of control measures. Stefan et al., (2021) show that even if intercropping does not necessarily reduce biomass or weed diversity, using cereals in association can play a pivotal role in reducing the pressure the weeds exert on cash crops. Therefore, it is preferable for intercropping systems to include cereals if weed control is one of the objectives.

CONCLUSIONS

The results obtained so far suggest that the intercropping systems could represent an approach of interest in all types of agriculture, but that it could be ideal for organic farming practice.

Embracing the intercropping system is more expensive, requires a high level of managerial skills, but, more importantly, a different philosophy on the part of the farmer, focusing on an ecosystem-oriented agriculture.

As long as cheap pesticides will not constitute a limiting factor for conventional farmers, by adopting a sets of environmental laws, they will be advantaged from production costs point of view.

There is an inverse relationship between the carbon footprint and crop yields.

Growing vegetables in an intercropping system increases productivity, maximizes the use of environmental resources and optimizes the use of inputs, balancing the system from an ecological point of view.

The restrictions on the use of pesticides and certain fertilizers that characterize organic farming make it suitable for enacting the intercropping system, as it corresponds exactly to its philosophy, patterns and methods. The small scale, as well as the biological and ecological diversity of farms in the unconventional growing systems makes them liable for intercropping as it does not require a completely different crop management.

Root system interactions can play an important role regarding the relationships between crops within intercropping (beneficial or competing) and nutrients. Thus, the complementary use of resources under the intercropping system improves the nitrogen content.

REFERENCES

Adesogan, A.T., Salawu, M.B., & Deaville, E.R. (2002). The effect on voluntary feed intake, in vivo digestibility and nitrogen balance in sheep of feeding grass silage or pea–wheat intercrops differing in pea to wheat ratio and maturity. Anim. Feed Sci. Tech. 96, 161–163.

Aksoy, U., Kayikcioglu, H., Kukul, Y.S., Hepaksoy, S., Can, H.Z., & Balci, B. (2003). An environmentally friendly technique to control salination: salt removing crops. Proceedings of the international symposium on sustainable use of plant biodiversity to promote new opportunities for horticultural production development. In: Duzyaman, E., Tuzel, Y. (Eds.), Acta Hortic. 598, 137-142.

Al-Musa, A. (1982). Incidence, economic importance, and control of tomato yellow leaf curl in Jordan. Plant Dis. 66:561–63

Altieri, M. A., Vanschoonhoven, A. & Doll, J. (1977). The ecological role of weeds in insect pest management systems: a review illustrated by bean (Phaseolus vulgaris) cropping systems. PANS 23 :195—205

Altieri, M.A., & Koohafkan, P. (2013). Strengthening resilience of farming systems: a key prerequisite for sustainable agricultural production. In: Wake up before it is too late: make agriculture truly sustainable now for food security in a changing climate. UNCTAD, TER13 report, Geneva, pp 56–60

Andow, D.A., Nicholson, A.G., Wien, H.C. & Willson, H.R. (1986). Insect populations on cabbage grown with living mulches. Environmental Entomology, 15, 293-299

Banik, P., Midya, A., Sarkar, B.K., & Ghose, S.S. (2006). Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. Eur. J. Argon. 24, 325–332

Bartzas, G., Zaharaki, D., & Komnitsas, K. (2015). Life cycle assessment of open field and greenhouse cultivation of lettuce and barley. Inf. Process. Agric. 2, 191-207. https://doi.org/10.1016/j.inpa.2015.10.001

Bedoussac, L. & Justes, E. 2010. The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. Plant and Soil 330:19–35.

Bedoussac, L., Journet, E.-P., Hauggaard-Nielsen, H., Naudin, C., Corre-Hellou, G., Jensen, E.S., Prieur, L., & Justes, E. (2015). Ecological principles underlying the increase of productivity achieved by cereal–grain legume intercrops in organic farming. A review. Agronomy for Sustainable Development 35:911–935.

Bingol, N.T., Karsli, M.A., Yilmaz, I.H., & Bolat, D. (2007). The effects of planting time and combination on the nutrient composition and digestible dry matter yield of four mixtures of vetch varieties intercropped with barley. J. Vet. Anim. Sci. 31, 297–302.

Bouws, H. & Finckh, M.R. (2008). Effects of strip intercropping of potatoes with non-hosts on late

blight severity and tuber yield in organic production. Plant Pathol. 57:916–27
Brooker, R.W., Bennett, A.E., Cong, W.F., 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., Schob, C., Shen, J.B., Squire, G., Watson, C.A., Zhang, C.C., Zhang, F.S., Zhang, J.L., & White, P.J. (2015). Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. New Phytol. 206, 107-117. https://doi.org/10.1111/nph.13132.
Buranday, R. P. & Raros, R. S. (1975). Effects of cabbage-tomato intercropping on the incidence and oviposition of the diamond-back moth, Plutella xylostella (L.). Philipp. Ent. 2: 369--374.
Carr, P.M., Horsley, R.D., & Poland, W.W. (2004). Barley, oat and cereal–pea mixtures as dryland forages in the northern Great Plains. Agron. J. 96, 677–684.
Cecílio Filho, A.B., Rezende, B.L.A., Barbosa, J.C., & Grangeiro, L.C. (2011). Agronomic efficiency of intercropping tomato and lettuce. An. Acad. Bras. Cienc. 83, 1109-1119. https://doi.org/10.1590/S000137652011000300029
Chapagain, T., & Riseman, A. (2014). Barley–pea intercropping: Effects on land productivity, carbon and nitrogen transformations. Field Crops Research, Vol. 166, 18-25 https://doi.org/10.1016/j.fcr.2014.06.014
Chavarria, M., Wherley, B., Thomas, J., Chandra, A., & Raymer, P. (2019). Salinity tolerance and recovery attributes of warm-season turfgrass cultivars. Hortscience 54, 1625-1631. https://doi.org/10.21273/HORTSCI13963-19
Chen, Y., Zhang, F., Tang, L., Zheng, Y., Li, Y., Christie, P., & Li, L. (2007). Wheat powdery mildew and foliar N concentrations as influenced by N fertilization and below ground interactions with intercropped faba bean. Plant Soil 291:1–13
Chirinda, N., Olesen, J.E., Porter, J.R., & Schjønning, P. (2010). Soil properties, crop production and greenhouse gas emissions from organic and inorganic fertilizer-based arable cropping systems. Agric Ecosyst Environ. 139:584–594.
Clavreul, J., Butnar, I., Rubio, V., & King, H. (2017). Intra- and inter-year variability of agricultural carbon footprints e a case study on field-grown tomatoes. J. Clean. Prod. 158, 156-164. https://doi.org/10.1016/j.jclepro.2017.05.004
Coskun, D., Britto, D.T., Shi, W.M., & Kronzucker, H.J. (2017). Nitrogen transformations in modern agriculture and the role of biological nitrification inhibition. Nature Plants 3, 17074. https://doi.org/10.1038/nplants.2017.74.
Den Hollander, N.G., Bastiaans, L., & Kropff, M.J. (2007). Clover as a cover crop for weed suppression in an intercropping design. II. Competitive ability of several clover species. European Journal of Agronomy 26:104–112
Diacono, M., Persiani, A., Castellini, M., Giglio, L., & Montemurro, F. (2021). Intercropping and rotation with leguminous plants in organic vegetables: Crop performance, soil properties and sustainability assessment. Biol. Agric. Hortic. Vol. 37, Issue 3, 141-167.
Dong, Q., Fei, L., Wang, C., Hu, S., & Wang, Z.L. (2019). Cadmium excretion via leaf hydathodes in tall fescue and its phytoremediation potential. Environ. Pollut. 252, 1406e1411. https://doi.org/10.1016/j.envpol.2019.06.079.
Du, L., Zheng, Z.C., Li, T.X., & Zhang, X.Z. (2019). Effects of irrigation frequency on transportation and accumulation regularity of greenhouse soil salt during different growth stages of pepper. Sci. Hort. 256, 108568. https://doi.org/10.1016/j.scienta.2019.108568.
Dumanski, J., Coote, D., Lucerek, G., & Lok, C. (1986). Soil conservation in Canada. J. Soil Water Conserv. 41, 204–210
Dyer, L., Oelbermann, M., & Echarte, L. (2012). Soil carbon dioxide and nitrous oxide emissions during the growing season from temperate maize–soybean intercrops. J. Plant Nutr. SoilSci.175, 394–400.
Fan, Y., Ge, T., Zheng, Y.L., Li, H., & Cheng, F.Q. (2016). Use of mixed solid waste as a soil amendment for saline-sodic soil remediation and oat seedling growth improvement. Environ. Sci. Pollut. Res. 23, 21407e21415. https://doi.org/10.1007/s11356-016-7360-3
Garrett, K.A., Nelson, R.J., Mundt, C.C., Chac´on, G., Jaramillo, R.E., & Forbes, G.A. (2001). The effects of host diversity and other management components on epidemics of potato late blight in the humid highland tropics. Phytopathology 91:993–1000
Guardia G., Aguilera E., Vallejo A., Sanz-Cobena A., Alonso-Ayuso L., & Quemada M. (2019). Effective climate change mitigation through cover cropping and integrated fertilization: A global warming potential assessment from a 10-year field experiment. J Clean Prod. 241:118307. doi:10.1016/j.jclepro.2019.118307
Guvenc, I., & Yildirim, E., (2006). Increasing productivity with intercropping systems in cabbage production. *Journal of Sustainable Agriculture*, 28, 29 – 44. https://doi.org/10.1300/J064v28n04_04 CrossrefGoogle Scholar
Hauggaard-Nielsen, H., Ambus, P., & Jensen, E.S. (2001). Interspecific competition, N use and interference with weeds in pea–barley intercropping. Field Crop Res. 70, 101–109.
Hauggaard-Nielsen, H., Gooding, M., Ambus, P., Corre-Hellou, G., Crozat, Y., Dahlmann, C., Dibet, A., von Fragstein, P., Pristeri, A., Monti, M., & Jensen, E.S. (2009). Pea–barley intercropping for efficient symbiotic N2-fixation, soil N acquisition and use of other nutrients in European organic cropping systems. Field Crop Res. 113, 64–71.
Hauggaard-Nielsen, H., Gooding, M., Ambus, P., Corre-Hellou, G., Crozat, Y., Dahlmann, C., Dibet, A., von Fragstein, P., Pristeri, A., Monti, M., & Jensen, E.S. (2009). Pea–barley intercropping for efficient symbiotic N2-fixation, soil N acquisition and use of other nutrients in European organic cropping systems. Field Crop Res. 113, 64–71.
Hauggaard-Nielsen, H., Jørnsgaard, B., Kinane, J., & Jensen, E.S. (2008). Grain legume-cereal

intercropping: the practical application of diversity, competition and facilitation in arable and organic cropping systems. Renew. Agric. Food Syst. 23:3–12

Hofsvang, T. (1991). The influence of intercropping and weeds on the oviposition of the brassica root flies (Delia radicum and D. flora/is). Norwegian Journal of Agricultural Sciences, 5, 349-356

Hu, L., Huang, Z., Liu, S., & Fu, J. (2012). Growth response and gene expression in antioxidant-related enzymes in two bermudagrass genotypes differing in salt tolerance. J. Am. Soc. Hortic. Sci. 137, 134-143

Hu, S., Liu, L., Zuo, S., Ali, M., & Wang, Z. (2020). Soil salinity control and cauliflower quality promotion by intercropping with five turfgrass species *Journal of Cleaner Production*, 266 art. no. 121991

Huang, B.R., DaCosta, M., & Jiang, Y.W. (2014). Research advances in mechanisms of turfgrass tolerance to abiotic stresses: from physiology to molecular biology. Crit. Rev. Plant Sci. 33, 141-189. https://doi.org/10.1080/07352689.2014.870411. SI.

Hwang, H.Y., Kim, G.W., Kim, S.Y., Haque, M.M., Khan, M.I., & Kim, P.J. (2017). Effect of cover cropping on the net global warming potential of rice paddy soil. Geoderma. 292:49–58.

Ilnicky, R.D. & Enache, A.J. (1992). Subterranean clover living mulch: an alternative method of weed control. Agriculture, Ecosystems and Environment, 40, 249-264.

IPCC (2007). Climate change 2007: the physical science basis. In: Solomon, S., Qin, D., Manning, M., Marquis, M., Averyt, K., Tignor, M.M.B., et al. (Eds.), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p. 996

Islam, M.K., Yaseen, T., Traversa, A., Ben Kheder, M., Brunetti, G., & Cocozza, C. (2016). Effects of the main extraction parameters on chemical and microbial characteristics of compost tea. Waste Manag. 52:62 68.doi:10.1016/j.wasman.2016.03.042

Jensen, E.S. (1996). Grain yield, symbiotic N2 fixation and interspecific competition for inorganic N in pea–barley intercrops. Plant Soil 18, 25–38.

Kalaycioglu, Z. & Erim, F.B. (2019). Nitrate and nitrites in foods: worldwide regional distribution in view of their risks and benefits. J. Agric. Food Chem. 67, 7205-7222.

Kaye, J.P., & Quemada, M. (2017). Using cover crops to mitigate and adapt to climate change. A review Agron Sustain Dev. 37(1):4. doi:10.1007/s13593-016-0410-x.

Khoshnevisan, B., Rafiee, S., Omid, M., Mousazadeh, H., & Clark, S. (2014). Environmental impact assessment of tomato and cucumber cultivation in greenhouses using life cycle assessment and adaptive neuro-fuzzy inference system. J. Clean. Prod. 73, 183-192. https://doi.org/10.1016/j.jclepro.2013.09.057

Kilic, C.C., Kukul, Y.S., & Anac, D. (2008). Performance of purslane (Portulaca oleracea L.) as a salt-removing crop. Agric. Water Manag. 95, 854-858. https://doi.org/ 10.1016/j.agwat.2008.01.019.

Knudsen, M.T., Hauggaard-Nielsen, H., & Jensen, E.S. (2004). Cereal–Grain Legume Intercropping in Organic Farming – A Danish Report. Riso National Laboratory, Plant Research Department, Roskilde, Denmark (retrieved: 26.02.14 from http://orgprints.org/9339/1).

Kolota, E., & Adamczewska-Sowinska, K. (2004). The effects of living mulches on yield, overwintering and biological value of leek. ActaHortic.638(638): 209 - 214.doi:10.17660/ActaHortic.2004.638.27.

Lauk, R., & Lauk, E. (2008). Pea–oat intercrops are superior to pea–wheat and pea–barley intercrops. Acta Agric. Scand. B 58, 139–144.

Leong, A.C. & Zaharah, A. (1991). Effects of different planting densities and schedules on chilli - cabbage intercropping. Mardi Research Journal, 19, 9-16.

Lepse, L., Dane, S., Zeipiņa, S., Domínguez-Perles, R., & Rosa, E. A. (2017). Evaluation of vegetable–faba bean (*Vicia faba* L.) intercropping under Latvian agro-ecological conditions. *Journal of the Science of Food and Agriculture*, 97, 4334– 4342. Wiley Online LibraryCASPubMedWeb of Science®Google Scholar

Lundberg, J.O., Weitzberg, E., & Gladwin, M.T. (2008). The nitrate-nitrite-nitric oxide pathway in physiology and therapeutics. Nat. Rev. Drug Discov. 7, 156-167. https://doi.org/10.1038/nrd2466.

Lyons, E.M., Landschoot, P.J., & Huff, D.R. (2011). Root distribution and tiller densities of creeping bentgrass cultivars and greens-type Annual bluegrass cultivars in a putting green. Hortscience 46, 1411-1417. https://doi.org/10.21273/ HORTSCI.46.10.1411.

Machado, R.M.A., & Serralheiro, R.P. (2017). Soil salinity: effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. Horticulturae 3, 30. https://doi.org/10.3390/horticulturae3020030

Manevski, K., Borgesen, C.D., Andersen, M.N., & Kristensen, I.S. (2015). Reduced nitrogen leaching by intercropping maize with red fescue on sandy soils in North Europe: a combined field and modeling study. Plant Soil 388, 67-85. https://doi.org/10.1007/s11104-014-2311-6.

Mariotti, M., Masoni, A., Ercoli, L., & Arduini, I. (2015). Nitrogen leaching and residual effect of barley/field bean intercropping. Plant, Soil and Environment 61:60–65.

Marousek, J., Kolar, L., Vochozka, M., Stehel, V., & Marouskova, A. (2017). Novel method for cultivating beetroot reduces nitrate content. J. Clean. Prod. 168, 60-62. https://doi.org/10.1016/j.jclepro.2017.08.233

Mead, R. & Willey, R.W. (1980). The concept of a 'Land Equivalent Ratio' and advantages in yield from intercropping. Experimental Agriculture, 16, 217-228.

Michel, V.V., Wang, J.F., Midmore, D.J., & Hartman, G.L. (1997). Effects of intercropping and soil amendment with urea and calcium oxide on the incidence of bacterial wilt of tomato and survival of soil-borne Pseudomonas solanacearum in Taiwan. Plant Pathol. 46:600–10

Montemurro, F., Persiani, A., & Diacono, M. (2018). Environmental sustainability assessment of horticultural systems: a multi-criteria evaluation approach applied in a case study in Mediterranean conditions. Agronomy. 8(7):98. doi:10.3390/ agronomy8070098.

Muhammad, I., Sainjub, U.M., Zhaoa, F., Khanc, A., Ghimired, R., Fua, X., & Wanga, J. (2019). Regulation of soil CO2 and N2O emissions by cover crops: A meta-analysis. Soil Tillage. Res.192:103–112. doi:10.1016/j.still.2019.04.020.

Müller-Schärer, H. (1996). Interplanting ryegrass in winter leek: Effect on weed control, crop yield and allocation of N-fertiliser. Crop Protection 15:641–648

Naudin, C., Aveline, A., Corre-Hellou, G., Dibet, A., Jeuffroy, M., & Crozat, Y. (2009). Agronomic analysis of the performance of spring and winter cereal-legume intercrops in organic farming. J. Agric. Sci. Technol. 3:17–28

Ntinas, G.K., Neumair, M., Tsadilas, C.D., & Meyer, J. (2017). Carbon footprint and cumulative energy demand of greenhouse and open-field tomato cultivation systems under Southern and Central European climatic conditions. J. Clean. Prod. 142, 3617-3626. https://doi.org/10.1016/j.jclepro.2016.10.106.

Oelbermann, M. & Echarte, L. (2011). Evaluating soil carbon and nitrogen dynamics in recently established maize–soybean intercropping systems. Eur. J. Soil Sci. 62, 35–41.

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

Ozalp, A., Yilmaz, S., Ertekin, C., & Yilmaz, I. (2018). Energy analysis and emissions of greenhouse gases of pomegranate production in Antalya Province of Turkey. Erwerbs-Obstbau. 60(4):321–329. doi:10.1007/s10341-018-0380-z.

Pereira, B.D.J., Filho, A.B.C., & La Scala Jr. N. (2021). Greenhouse gas emissions and carbon footprint of cucumber, tomato and lettuce production using two cropping systems. J. Clean. Prod. 282, 124517

Pergola M., Persiani A., Palese A.M., Di Meo V., Pastore V., D'Adamo C., & Celano C. (2018). Composting: the way for a sustainable agriculture. Appl Soil Ecol. 123:744–750. doi:10.1016/j.apsoil.2017.10.016.

Phillips, M. L. (1977). Some effects of inter-cropplng Brussels sprouts and tomatoes on infestations of Plutella maculipennis (Curt.) and Aleyrodes brassicae (Walk.). Unpublished M. Sc. thesis, Univ. London

Pishgar-Komleh, S.H., Akram, A., Keyhani, A., Raei, M., Elshout, P.M.F., Huijbregts, M.A.J., & van Zelm, R. (2017). Variability in the carbon footprint of open-field tomato production in Iran - a case study of Alborz and East-Azerbaijan provinces. J. Clean. Prod. 142, 1510-1517. https://doi.org/10.1016/ j.jclepro.2016.11.154

Plawecki, R., Pirog, R., Montri, A., & Hamm, M.W. (2014). Comparative carbon footprint assessment of winter lettuce production in two climatic zones for Midwestern market. Renew. Agric. Food Syst.29, 310-318. https://doi.org/10.1017/S1742170513000161

Pratibha, G., Srinivas, I., Rao, K.V., Raju, B.M.K., Thyagaraj, C.R., Korwar, G.R., Venkateswarlu, B., Arun Shanker, K., Deepak Choudhary, K., Srinivas Rao, K., & Srinivasarao, Ch. (2015). Impact of conservation agriculture practices on energy use efficiency and global warming potential in rainfed pigeonpea-castor systems. Europ J Agron. 66:30–40. doi:10.1016/j. eja.2015.02.001.

Ramkat, R.C., Wangai, A.W., Ouma, J.P., Rapando, P.N., & Lelgut, D.K. (2008). Cropping system influences Tomato spotted wilt virus disease development, thrips population and yield of tomato (Lycopersicon esculentum). Ann. Appl. Biol. 153:373–80

Rathod, K.S., Velmurugan, S., & Ahluwalia, A. (2016). A 'green' diet-based approach to cardiovascular health? Is inorganic nitrate the answer? Mol. Nutr. Food Res. 60, 185-202. https://doi.org/10.1002/ mnfr.201500313. SI

Rezende, B.L.A., Cecílio Filho, A.B., Porto, D.R.D.Q., Barros Junior, A.P., Silva, G.S. da, Barbosa, J.C., & Feltrim, A.L. (2010). Consorcios de alface crespa e pepino em funçao da populaçao do pepino e epoca de cultivo. Interciencia 35, 374-379.

Ross, S.M., King, J.R., Donovan, J.T.O., & Spaner, D. (2004). Intercropping berseem clover with barley and oat cultivars for forage. Agron. J. 96, 1719–1729.

Santos, R. H., Gliessman, S. R., & Cecon, P. R. (2002). Crop interactions in broccoli intercropping. *Biological Agriculture & Horticulture*, 20, 51–75. https://doi.org/10.1080/01448765.2002.9754948 CrossrefWeb of Science®Google Scholar

Schröder, D., & Köpke, U. (2012). Faba bean (*Vicia faba* L.) intercropped with oil crops–a strategy to enhance rooting density and to optimize nitrogen use and grain production? *Field Crops Research*, 135, 74– 81. CrossrefWeb of Science®Google Scholar

Schultz, B.B., Phillips, C., Rosset, P. & Vandermeer, J. (1982). An experiment in intercropping tomatoes and cucumbers in southern Michigan, USA. Scientia Horticulturae, 18, 1-8.

Sekamatte, B.M., Latigo, M.O., & Smith, M.R.A. (2003). Effects of maize–legume intercrops on termite damage to maize, activity of predatory ants and maize yields in Uganda. CropProtect.22,87–93.

Shanmugam, S., Hefner, M., Pelck, J. S., Labouriau, R., & Kristensen, H. L. (2021). Complementary resource use in intercropped faba bean and cabbage by increased root growth and nitrogen use in organic production. *Soil Use and Management.* 38 (1), 729-740, https://doi.org/10.1111/sum.12765

Simpson, C.R., Franco, J.G., King, S.R., & Volder, A. (2018). Intercropping halophytes to mitigate salinity stress in watermelon. Sustainability 10, 681. https://doi.org/10.3390/su10030681.

Soliman, W.S., Sugiyama, S., & Abbas, A.M. (2018). Contribution of avoidance and tolerance strategies towards salinity stress resistance in eight C-3 turfgrass species. Hort. Environ. Biotech. 59, 29-36. https://doi.org/10.1007/s13580-018-0004-4

Stefan, L., N. Engbersen, & Sch ̈ob, C. (2021). Crop–weed relationships are context-dependent and cannot fully explain the positive effects of intercropping on yield. Ecological Applications 00(00):e02311. 10.1002/eap.2311

Su, S., Ren, L., Huo, Z., Yang, X., Huang, Q., Xu, Y., Zhou, J., & Shen, Q. (2008). Effects of intercropping watermelon with rain fed rice on Fusarium wilt and the microflora in the rhizosphere soil. Sci. Agric. Sin. 41:704–12

Sun, Y., Zhou, T., Wang, Y., Chen, J., He, X.H., Li, C.Y., & Zhu, Y.Y. (2006). Effect of intercropping on disease management and yield of chilli pepper and maize. Acta Hortic. Sin. 33:995–1000

Tahvanainen, J. O. & Root, R. B. (1972). The influence of vegetational diversity on the population ecology of a specialised herbivore, Phyllotreta cruciferae (Coleoptera: Chrysomelidae). Oecologia 10: 321--346.

Tang, Q. X., Tewolde, H., Liu, H. B., Ren, T. Z., Jiang, P. A., Zhai, L. M., Lei, B. K., Tao, L., & Liu, E. K. (2018). Nitrogen uptake and transfer in broad bean and garlic strip intercropping systems. *Journal of Integrative Agriculture*, 17, 220 230.https://doi.org/10.1016/S20953119(17)61772-6 CrossrefCASWeb of Science®Google Scholar

Theunissen, J. & den Ouden, H. (1980). Effects of intercropping with Spergula arvensis on pests in Brussels sprouts. Entomologia Experimentalis et Applicata, 27, 260-268

Theunissen, J. & Schelling, G. (1993). Suppression of Thrips tabaci populations in intercropped leek. Mededelingen Faculteit Landbouwwetenschappen Universiteit Gent, 58, 2a, 383-390.

Theunissen, J. & Schelling, G. (1996). Pest management by intercropping: suppression of thrips and rust in leek. International Journal of Pest Management, 42, 227-234

Theunissen, J. (1994b). Effects of intercropping on pest populations in vegetable crops. IOBCI WPRS Bulletin, 17, 153-158.

Theunissen, J., Booij, C.J.H. & Lotz, L.A.P. (1995). Effects of intercropping white cabbage with clovers on pest infestation and yield. Entomologia Experimentalis et Applicata, 74, 7-16.

Thilakarathna, M. S., McElroy, M. S., Chapagain, T., Papadopoulos, Y. A., & Raizada, M. N. (2016). Belowground nitrogen transfer from legumes to non-legumes under managed herbaceous cropping systems. A Review. *Agronomy for Sustainable Development*, 36, 58. CrossrefCASWeb of Science®Google Scholar

Thorup-Kristensen, K. & van den Boogaard, R. (1998). Temporal and spatial root development of cauliflower (Brassica oleracea L. var. botrytis L.). Plant Soil 201, 37-47. https://doi.org/10.1023/A:1004393417695

Thorup-Kristensen, K., Dresboll, D.B., & Kristensen, H.L. (2012). Crop yield, root growth, and nutrient dynamics in a conventional and three organic cropping systems with different levels of external inputs and N re-cycling through fertility building crops. European Journal of Agronomy 37:66–82.

Tingey, W.M. & Lamont, W.J. (1988). Insect abundance in field beans altered by intercropping. Bulletin of Entomological Research, 78, 527-535.

Torrellas, M., Anton, A., Lopez, J.C., Baeza, E.J., Parra, J.P., Munoz, P., & Montero, J.I. (2012). LCA of a tomato crop in a multi-Tunnel greenhouse in Almeria. Int. J. Life Cycle Assess. 17, 863-875. https://doi.org/10.1007/s11367-012-0409-8

Uchino, H., Iwama, K., Jitsuyama, Y., Yudate, T., & Nakamura, S. (2009). Yield losses of soybean and maize by competition with interseeded cover crops and weeds in organic-based cropping systems. Field Crops Research 113:342–351.

Uddin, M.K., Juraimi, A.S., Ismail, M.R., & Alam, M.A. (2012). The effect of salinity on growth and ion accumulation in six turfgrass species. Plant Omics 5, 244-252

Uvah, I.I.I. & Coaker, T.H. (1984). Effect of mixed cropping on some pests of carrots and onions. Entomologia Experimentalis et Applicata, 36, 159-167

Vandermeer, J. (1989). The Ecology of Intercropping. Cambridge University Press; Cambridge.

Vansteenkiste, J., Van Loon, J., Garre, S., Pages, L., Schrevens, E., & Diels, J. (2014). Estimating the parameters of a 3-D root distribution function from root observations with the trench profile method: case study with simulated and field-observed root data. Plant Soil 375, 75-88. https://doi.org/10.1007/s11104-013- 1942-3.

Wang, Y.Y., Cheng, Y.H., Chen, K.E., & Tsay, Y.F. (2018). Nitrate transport, signaling, and use efficiency. Annu. Rev. Plant Biol. 69, 85e122. https://doi.org/10.1146/annurev-arplant-042817-040056.

Whitmore, A.P. & Schröder, J.J. (2007). Intercropping reduces nitrate leaching from under field crops without loss of yield: A modelling study. European Journal of Agronomy 27:81–88.

Wiedmann, T. & Minx, J. (2007). A definition of carbon footprint. In: Pertsova, C.C. (Ed.), Ecological Economics Research Trends. Nova Science Publishers, Hauppauge NY, USA, 1-11.

Wit, C.T. de & van den Bergh, J.P. (1965). Competition between herbage plants. Netherlands Journal of Agricultural Science, 13, 212-221

Xia, J.B., Ren, J.Y., Zhang, S.Y., Wang, Y.H., & Fang, Y. (2019). Forest and grass composite patterns improve the soil quality in the coastal saline-alkali land of the Yellow River Delta, China. Geoderma 349, 25-35. https://doi.org/10.1016/j.geoderma. 2019.04.03

Xiao, J., Yin, X., Ren, J., Zhang, M., Tang, L., & Zheng, Y. (2018). Complementation drives higher growth rate and yield of wheat and saves nitrogen fertilizer in wheat and faba bean intercropping. *Field Crops Research*, 221, 119–129. https://doi.org/10.1016/ j.fcr.2017.12.009 CrossrefWeb of Science®Google Scholar

Yildirim, E. & Guvence, I. (2005). Intercropping based on cauliflower: more productivity, profitable and highly sustainable. Eur. J. Agron. 2, 11–18.

Zarei, M.J., Kazemi, N., & Marzban, A. (2019). Life cycle environmental impacts of cu-cumber and tomato production in open-field and

greenhouse. J. Saudi Soc. Agric. Sci. 18, 249-255. https://doi.org/10.1016/j.jssas.2017.07.001
Zewde, T., Fininsa, C., Sakhuja, P.K., & Ahmed, S. (2007). Association of white rot (Sclerotium cepivorum) of garlic with environmental factors and cultural practices in the North Shewa highlands of Ethiopia. Crop Prot. 26:1566–73
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.https://doi.org/10.1023/A:1022352229863 CrossrefCASWeb of Science®Google Scholar
Zhang, Y.F., Li, Y.P., Sun, J., & Huang, G.H. (2020). Optimizing water resources allocation and soil salinity control for supporting agricultural and environmental sustainable development in Central Asia. Sci. Total Environ. 704, 135281. https:// doi.org/10.1016/j.scitotenv.2019.135281
Zu, Y., Hu, W., Wu, B., Zhan, F., & Li, Y. (2008). Effect of chilli pepper intercropping system on nutrient utilization, main diseases and pests and yield of chilli pepper. J. Wuhan Bot. Res. 26:412–16