Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 4, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

BIODIVERSITY IN VEGETABLE CULTURE AND ITS ROLE IN THE SUSTAINABILITY OF AGROECOSYSTEMS. A REVIEW

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Abstract

Biodiversity plays an essential role in vegetable agroecosystems, providing multiple benefits for soil health, natural pest control, and climate change adaptation. This article examines the role of biodiversity in vegetable cultivation and the impact of diversified agricultural practices on the sustainability and health of agroecosystems. The research methods were represented by: studying specialized and scientific literature, structuring the references on the topics of interest, critical evaluation of the ideas belonging to different authors, exposing our own ideas and drawing the main conclusions on the role played by biodiversity in vegetable culture in the sustainability of agroecosystems. The study shows that diversifying vegetable crops through species rotation, intercropping, the use of cover crops, and applying organic mulch is essential for maintaining biodiversity in agroecosystems. These methods contribute to soil health, reduce the need for chemical inputs, and enhance ecological stability. Thus, they represent effective solutions for promoting sustainable agriculture and a healthier, more balanced agricultural environment, offering a solid foundation for resilient and adaptable agriculture.

Key words*: biodiversity, agroecosystems, legumes, cover crops, sustainable agriculture*

INTRODUCTION

The intensification of modern agriculture has led to the adoption of monoculture practices, which has increased the risk of biodiversity loss and affected the stability of agroecosystems [4]. Biodiversity, especially in vegetable cultivation, plays a fundamental role in supporting soil health, attracting natural pest predators, and maintaining a stable ecological balance. Various vegetable species and the use of ecological practices, such as crop rotation and intercropping, contribute to biodiversity conservation and provide a foundation for the development of sustainable agriculture [3], [13].

Plant diversity in vegetable agroecosystems contributes to adaptation and resilience to climate variations. Agricultural systems with a high diversity of species can respond better to climate stress, such as drought or extreme temperatures, through ecological mechanisms that help maintain soil moisture and productivity [18], [85]. The study by [61] showed that crop diversification can enhance agroecosystem resilience, allowing them to adapt more easily to climate variability. For example, cover crops and intercropped crops help maintain lower soil surface temperatures, reduce moisture loss, and protect crops from extreme temperatures. In the long term, implementing diversification practices in vegetable cultivation could reduce dependence on synthetic pesticides and fertilizers, thereby contributing to increased ecological and food security [61].

Vegetable species play an essential role in maintaining and enhancing the biodiversity of agroecosystems. They contribute to soil health, natural pest control, and support balanced ecosystems through complex nutrient cycles and beneficial interactions with microorganisms and local fauna. The diversity of vegetable species includes not only traditional varieties but also legumes, cover crops, and crops with increased genetic resistance, all of which contribute to a sustainable agricultural system.

Biodiversity in agroecosystems helps conserve water and prevent soil erosion by providing permanent ground cover and improving soil structure.

Cover crops and intercropped plants help safeguard soil from wind and water erosion, enhancing water retention and minimizing nutrient loss through runoff.

[20] study demonstrated that cover crops like clover and mustard effectively mitigate soil erosion and enhance water retention, promoting long-term soil fertility and stability.

Another study, conducted by [58], highlights the benefits of biodiversity in reducing soil erosion and conserving water, showing that better-structured soil has a greater capacity for water infiltration, thus preventing soil degradation and preserving water resources.

Aromatic and medicinal plants, such as rosemary (*Rosmarinus officinalis*) and lavender (*Lavandula* spp.), are particularly valuable for attracting natural predators and pollinators, thereby contributing to pest control and improving vegetable productivity. These plants have a high content of essential oils that deter many harmful species while attracting beneficial insects, such as bees and parasitic wasps. According to the research by [92], adding aromatic plants to vegetable crops increases faunal biodiversity and may help reduce the need for pesticides.

A study by [67] showed that the use of organic mulch in vegetable cultivation supports a greater diversity of beneficial soil organisms, such as bacteria and fungi. Organic mulch also contributes to stabilizing nutrient levels and improving soil health, thus facilitating long-term productivity.

The purpose of this paper is to examines the role of biodiversity in vegetable cultivation and the impact of diversified agricultural practices on the sustainability and health of agroecosystems.

MATERIALS AND METHODS

Information sources were represented by specialized and scientific publications on innovative technologies, reports, projects and studies at both national and international levels were consulted.

The studied literature was structured based on the topics of interest and the authors' ideas have been critically evaluated and commented.

The content of this research work includes the results of the bibliographic analysis focused on specific vegetable farming practices, such as crop rotation, the use of cover crops and the application of organic mulch, with the aim of synthesizing best practices and their impact on sustainability.

RESULTS AND DISCUSSIONS

Legumes and their contribution to biodiversity conservation

The production of legumes provides numerous ecosystem services, facilitating land use diversification and supporting biodiversity in agroecosystems due to their ability to fix atmospheric nitrogen in the soil.

In the European Union, protein crops occupy only 1.5% of arable land, compared to 14.5% globally [101]. A relatively small percentage of peas (*Pisum sativum* L.) (11–15%) and fava beans (*Vicia faba* L.) (9–14%) cultivated in Europe are designated for human consumption, with the majority being allocated for animal feed, a less efficient method of protein production for human diets [17]. In Northern Europe, peas (*Pisum sativum* L.) and fava beans (*Vicia faba* L.) have long been integral crops in agricultural practices [94]. Protein-rich crops such as fava beans (*Vicia faba* L.), peas (*Pisum sativum* L.), chickpeas (*Cicer arietinum* L.), lupins (*Lupinus albus* L.), and soybeans (*Glycine max* L.) possess the unique ability to fix atmospheric nitrogen, making them essential for low-input farming systems that aim to lower greenhouse gas emissions [60].

These crops can provide significant amounts of nitrogen to subsequent crops in the rotation, reducing the need for mineral fertilizers [101]. In addition, they improve soil health and support crop protection [51]. Other studies have shown that adding legumes to cereal rotations has positive effects on cereal yields and gross margins, compared to monocultures [102].

[71] demonstrate that intercropping maize (*Zea mays* L.) with legumes increases N uptake. Additionally, nitrogen fixation

provides significant residual benefits, enhancing the productivity of subsequent maize crops [1].

Recently, legume crops have gained importance due to rising prices for animal feed and food proteins, fertilizers and fuel, in addition to sustainability concerns. The impact of introducing legume (*Vicia faba* L.) into dominant cereal crop production systems, typical of southwestern Finland, was investigated by [98].

Traditional varieties and indigenous species of vegetables

The wide array of traditional crops once cultivated on a sustainable scale in various regions of the world has been replaced by a limited selection of major crops grown in large-scale monocultures [49]. This shift has significantly reduced the diversity of species upon which global food security depends [96]. Over the past 50 years, reliance on commercial hybrids and advanced cultivars, coupled with the marginalization of traditional local species, has drastically diminished horticultural and agricultural biodiversity. Additionally, factors such as habitat loss, climatic changes, and evolving cultural practices have further narrowed the spectrum of non-commercial crops commonly utilized by humans. Globally, vegetable genetic resources are being lost at an estimated rate of 1%–2% annually [25], primarily due to changes in how the human population exploits the world's edible plant resources [86].

There is a need of investment in research breeding and cultivar development in traditionally open-pollinated cultivars and in the minor and so-called “forgotten” vegetables. More investments in this area will mean cheaper cultivars for growers to choose from and more preservation of vegetable biodiversity.

Indigenous and traditional vegetables exhibit remarkable biodiversity, thriving in specific marginal soil and climatic conditions with minimal reliance on external inputs [28], [48]. Incorporating these traditional vegetables into current production systems enhances their heterogeneity, which in turn improves resilience to both abiotic and biotic stresses [74].

[61] highlights examples where diverse agroecosystems successfully suppressed pests and diseases while buffering against climate variability.

Several solanaceous crops, including species of Solanum, Capsicum, and Physalis, are cultivated beyond their original centers of domestication. Recently, there has been growing interest in novel Solanaceae crops for European cultivation [79], [87], [89], [88], [68], [69]. This emerging focus underscores the potential of lesser-known species, warranting further exploration and research. As climate change continues to shift environmental parameters, many of these crops could potentially expand beyond their traditional climatic zones [86].

The initial step in launching new breeding programs for indigenous vegetable crops is their thorough characterization, a process that should begin promptly across various countries. The assumption that these crops are inherently and permanently "resistant to pests and diseases" compared to conventional or globally cultivated vegetable crops is likely a misconception. When indigenous crops transition to mainstream production, they will inevitably face a broad spectrum of pests and diseases, potentially undermining farm productivity. To ensure sustainable and profitable cultivation, defensive strategies such as selective breeding, grafting, integrated pest management, and robust agronomic practices will be essential to achieve high-quality and sufficient crop yields [55].

Cover crops

Cover crops, such as red clover (*Trifolium pratense* L.) and rapeseed (*Brassica napus* L.), are essential for soil protection against erosion and improving microbial biodiversity. These crops provide constant soil cover, preventing nutrient runoff and offering a favorable habitat for beneficial microorganisms and insects. In a study conducted by [19], it was shown that the use of cover crops reduces the need for chemical inputs and supports soil structure by increasing microbial activity.

Cover crops also contribute to pest control by stimulating populations of natural predators and pollinators, thus maintaining an ecological balance within the agroecosystem [59].

Cover crops are plants grown between production cycles of main crops to protect the soil from erosion, increase organic matter content, and improve soil fertility or as feed for animals. They also provide habitat for a wide range of beneficial organisms, including predatory insects, bacteria, and fungi.

The decomposing residues of brassica cover crops, through the release of glucosinolates, aid in the control of parasitic nematodes [81]. In addition, during the same phase, they can cause chemical and physical changes in the soil and facilitate root penetration of the next crop and act as a buffer for the soil [50]. Several studies confirm that the use of legume cover crops in crop rotations, such as clover (*Trifolium pratense* L.) and alfalfa (*Medicago sativa* L.), and graminaceous cover crops, such as ryegrass (*Trifolium pratense* L), oat (*Medicago sativa* L.), and barley (*Hordeum vulgare* L.*)*, enhance the yields of the following cash crop [52], [64], [24].

Studies conducted by [19], demonstrate that cover crops such as red clover (*Trifolium pratense* L.) and mustard (*Brassica napus* L.) improve soil health by enriching it with nutrients, reducing the need for chemical fertilizers, and helping regulate pest populations. Additionally, [59] emphasized that the use of cover crops increases biodiversity by attracting pollinators and through biological pest control.

There are various crop alternatives to be used as vegetative cover, such as grains, legumes, root crops and oil crops. All of them are of great benefit to the soil, however some cover crops have certain attributes, which need to be kept when planning a rotation scheme [2], [23]. It is important to start the first years of conservation agriculture with cover crops that leave a lot of residues on the soil surface, which decompose slowly (because of the high carbon/Nitrogen ratio, an indicator for nitrogen limitation of plants and other organisms). The adoption of cover crops in agro-ecosystems provides multiple benefits to the agro-ecosystems.

To maximize the agro-ecological functions, complementing and synergizing the effects, cover crops are usually cultivated in a mixture. Very important, in the constitution of these mixes is to use the functional complementarity of the species [21]. The potential application of crop mixtures (involving cereal, legume, and even crucifer cover crops) is an issue of strategic interest when designing low-C cropping systems such as in Mediterranean areas.

In addition, Brassicaceous over crops are chosen to improve soil penetration resistance due to taproot growth but are also used as a highly effective catch crop [11]. For example, mixing radish with rye can mitigate both soil compaction and soil erosion risks due to the bio-drilling potential of radish and abundant aboveground biomass cover produced by rye [22], [82].

Radish (*Raphanus raphanistrum* subs. *sativus*), a widely used and highly beneficial cover crop, catch soil nutrients, especially nitrogen [93]. In that sense, the use of cruciferous species as cover crops could allow the natural control of potential diseases.

[99] showed that radish (*Raphanus raphanistrum* subsp. *sativus*) or brown mustard (*Brassica juncea* L.) as a biofumigant crop could be effective against plant-parasitic nematodes without compromising on soil health or changing the structure of the nematode community. Furthermore, [6] revealed that using radish (*R. sativus*) and arugula (*Eruca sativa*) as winter cycle plants before plants that are susceptible to the root-knot nematode *Meloidogyne arenaria* would help to reduce gall index, egg masses and consequently damage and also increase crop yields. Last, leguminous vover crops are recognized as the most effective when maximizing nitrogen (N) input becomes the priority [35]. Indeed, leguminous cover crops can deposit significant amounts of N in the soil during growth and have the ability to acidify the rhizosphere by facilitating the uptake of insoluble phosphorous into the soil [72], [100]. According to [91], the presence of *Trifolium subterraneum,* for three consecutive years, determined a considerable increase in ammoniacal nitrogen, nitric nitrogen, and the N cycle bacteria.

Furthermore, [39] revealed that the mitigation effect of the legume (vetch) cover crops mainly due to the reduction of synthetic N inputs in the subsequent cash crop as well as a decrease in indirect N_2O emissions from NO_3^- leaching and an increase in C sequestration due to an intensive photosynthetic activity.

[29] have observed that the specific use of *Trifolium repens* and *Vicia villosa* as cover crops can improve soil quality and yield in apple orchards. In long-term cropping systems such as orchards, cover crops have economic benefits because, in addition to protecting soil against water and wind erosion, they can contribute, through residue deposition, to nutrient recycling, increased soil health and reduced mineral fertilization needs [27]. This could be useful on vineyard and olive tree systems that are generally affected by erosion due to the high loss of organic matter and excessive tillage operations [7]. Other tree systems that have the same issues are those consisting of almond [65], apricot [56] and persimmon orchards [83]. Several studies showed that the cultivation of cover crops is an effective solution to minimize soil erosion in these orchards caused by intensive tillage, excessive mineral fertilizer applications and herbicide use and, therefore, preserve soil from the risk of desertification [54], [8].

[36] observed that the use of cover crops could reduce soil losses by 3.8 to 0.7 Mg ha^{-1} in a vineyard.

[76] showed that using cover crops reduces by 27% annual water runoff and can be used as an agronomic strategy for improving water use efficiency.

Aromatic and medicinal plants

Intercropping medicinal and aromatic plants with various horticultural crops plays a significant role in reducing post-harvest yield losses, preserving fruit quality, and extending shelf life during storage. Additionally, the essential oil content, yield, and composition of medicinal and aromatic plants are influenced by the interspecific competition present within the intercropping system. [32], [77].

According to the experimental result of [57] intercropping of some aromatic plants with tomato (*Solanum lycopersicum* L.) protect the infestation of *Tuta absoluta* on tomato. The inclusion of rosemary (*Rosmarinus officinalis* L.) with onion elevated yield advantage and competitiveness over sole planted crop per unit area as indicated by higher LER and relative crowding coefficient. This enables to prevent the insect pest attack on onion [5]. Planting marigolds (*Calendula officinalis L.)* between tomatoes protects the tomato plants from harmful root-knot nematodes in the soil and increase the marketable fruit yield of tomato by trapping different insects and pest attack and the like [31]. Marigold repels nematodes, tomato worm, slugs and general garden pests [38] found that intercropping of tomato with African marigold (*Tagetes erecta* L.) reduced early blight (*Alternaria solani*) of tomato (*Solanum lycopersicum* L.). Intercropping marigold (*Tagetes erecta* L.) for nematode management also appeared to reduce numbers of aphids and whiteflies, and resulted in lower levels of virus in tomato [103].

Tomato (*Solanum lycopersicum* L.) and basil (*Ocimum basilicum* L.) are common pairs that are intercropped [70]. Several studies reported the performance of intercropping of aromatic and medicinal plant species with selected major horticultural crops in different countries as cited by [70], the experimental results of [73], [75]. [37] reported intercropping of onion (*Allium cepa* L.) with basil (*Ocimum basilicum* L.) at a 1:1-row arrangement could provide farmers with the best yield advantage and income over sole planting of component (onion) crops. Basil and tomato are companion plants that have similar lighting and watering needs, some even say tomatoes (*Solanum lycopersicum* L.) taste better when they neighbour basil (*Ocimum basilicum* L.) [12].

Application of organic mulch

The application of organic mulch is an effective technique for conserving soil moisture, reducing weed growth, and improving soil structure [80]. Organic mulch helps increase soil biodiversity by providing a habitat and a constant source of organic matter for soil organisms. It can also contribute to maintaining soil temperature and improving water retention capacity.

Numerous studies have demonstrated that intercropping and living mulches can positively influence pest and disease management as well as weed control [40], [41], [45], [46], [47], [53], [90] . However, this outcome cannot be universally applied and must be evaluated on a case-by-case basis [66]. The effectiveness of these practices often depends on various factors, including the cropping systems and the arthropod species involved in the experiments.

[30] highlight the overall positive impact of the living mulch technique on plant-soil systems, evidenced by increased soil biodiversity and the absence of significant negative effects on pest abundance.

In the study by [30], the effects of a ‘cover crop–vegetable cash crop’ intercropping system on arthropod dynamics and biodiversity were analyzed across four European countries: Italy, Denmark, Germany, and Slovenia. Soil arthropod fauna served as an indicator for comparing the ecosystem services provided by living mulch systems versus sole crop systems. The findings revealed that the living mulch technique had no adverse effect on the infestation of cabbage caterpillar (*Pieris* spp.), a key pest of cabbage [14], [15], [16].

In Denmark, aphid populations were notably higher in the sole crop system compared to the living mulch system. In Italy, a high rate of larval parasitization was observed, with parasitization levels reaching 88% in living mulch systems versus 63% in sole crop systems during one year of the study. Additionally, the living mulch positively influenced the activity density of Carabid beetles, enhancing species diversity and evenness in Italy and Slovenia and increasing the activity density of specific taxa in Slovenia and Denmark.

Overall, the results demonstrate that living mulch techniques contribute positively to arthropod biodiversity in plant-soil systems, enhancing soil biodiversity and showing no detrimental effects on the density of canopy pests. These findings suggest that living mulch can provide valuable ecosystem services while maintaining effective pest control [26], [33], [63].

In conclusion, a notable finding from our study is that the use of living mulch in cauliflower cultivation did not lead to an increase in pest infestation, demonstrating the absence of any detrimental effects associated with this technique.

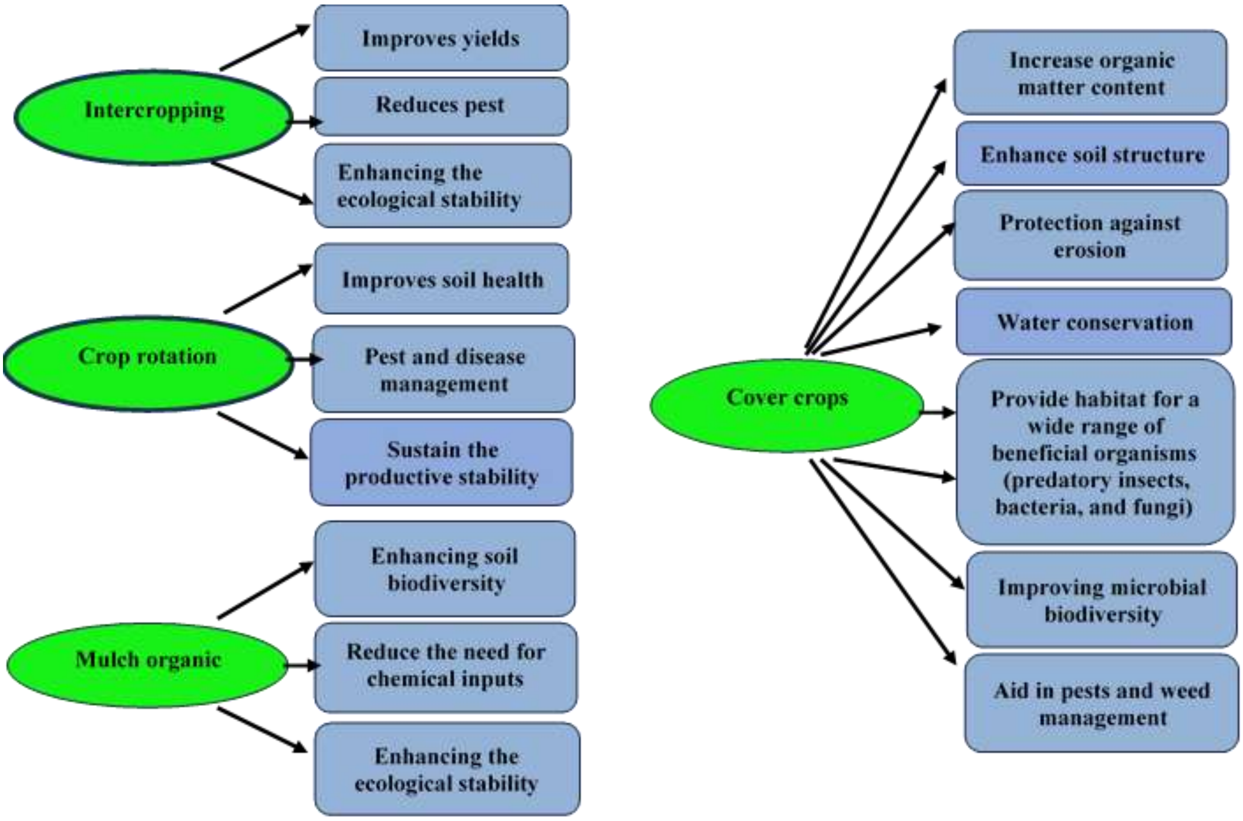
When vegetables are undersown in living mulches or row intercropped with cover crops or other vegetable crops, they are found to reduce herbivorousinsects and damage caused by them [42], [43], [44], [97], [104].

These systems (living mulches, intercropping) create diverse habitats that are generally less favorable for herbivores and/or more conductive for natural enemies [84].

However, herbivore response to diverse habitats could not be explained by a single ecological theory and may depend on the behavior of herbivores (host finding, host acceptance, etc.) to the specific habitat type [44].

The primary mechanisms behind the pest-suppressive effects of living mulches and intercrops are attributed to the disruption of host-plant detection, chemically-based repellency, impacts on insect pests and their natural enemies, and potential competition between the cash crop and adjacent non-crop vegetation [34], [62]. Although these techniques can function independently as pest management strategies, their effectiveness is enhanced when integrated with other approaches, including chemical controls (used selectively, such as in trap cropping), cultural practices, and biological control methods [9], [10] [78]. Below, we discuss the main mechanisms underlying the effects of living mulches and intercrops on pest suppression [95].

Further development of such methods, as shown in Figure 1, promote biodiversity and provide favorable conditions for agriculture based on ecological principles are expected to reduce chemical inputs (e.g., insecticides) (a), thus impacting positively the society and the environment to move towards sustainability in vegetable production systems (b).



(**a**) (**b**)

Fig. 1. Methods of diversifying vegetable crops for the sustainability of biodiversity in agroecosystems (a) and The ecological and economic impact of using these methods (b)
Source: Authors' own conception.

The economic impact of the use of various methods for diversifying vegetable crops

The use of a large variety of crops gives a new chance to farmers to develop their agri-business in terms of a higher production, diversification of the products obtained, improving the acquisition price at the farm gate, raising their incomes and profit.

Consumers will have at their disposal more alternatives from which to choose the most suitable one to cover their needs.

Industry will benefit of a large range of raw materials to transform them into new products which will enlarge the domestic market and also could become an object for commercialization on the international market.

In the rural communities, where agriculture plays the main role, new opportunities of jobs could be created by extending and diversifying the cultivated crops.

The new crops could increase value-added, create market niches and generate income streams along the value chain.

The implementation of a large range of vegetal crops and enlarging the use of various the methods to cultivate them in a friendly manner with the environment will contribute to production diversification, to the increase of revenues, to the reduction of the market dependence on commodity crops, and to the enhancement of the competitiveness of farmers in global markets [13].

CONCLUSIONS

There is a lot of scientific evidence that supports the adoption of cover crops as a valid solution for allowing the ecological transition of modern and intensive systems toward sustainable farming systems. Several beneficial effects could be accounted for following the cultivation of cover crops, such as the improvement of soil health, enhancement of nutrient cycling, carbon sequestration and reduction of greenhouse gas emissions, reduction of synthetic fertilizers, and economic returns [82]. Therefore, the introduction of cover crops into agricultural systems can sustain the productive stability of cash crops and increase soil fertility through organic matter accumulation. Furthermore, cover crops may enhance soil structure, water conservation, and aid in pests and weed management.

Agricultural practices such as crop rotation, intercropping, the use of cover crops, and the application of organic mulch are essential for maintaining biodiversity in agroecosystems. These methods contribute to soil health, reduce the need for chemical inputs, and enhance ecological stability. Thus, they represent effective solutions for promoting sustainable agriculture and a healthier, more balanced agricultural environment, providing a solid foundation for resilient and adaptable farming.

REFERENCES

[1]Abdelsalam, A., Fouda, T., 2023, Determination of color properties of some seeds, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 23(1), 15-19.

[2]Ahmadnia, F., Ebadi, A., Hashemi, M., Ghavidel, A., 2020, Investigating the short time effect of cover crops on physical and biological properties of soil. J. Water Soil Conserv. 26, 277–290.

[3]Altieri, M. A., 1999, The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment, 74(1-3), 19-31.

[4]Armengot, L., Barbieri, P., Andres, C., Milz, J., Schneider, M., 2016, Cacao agroforestry systems have higher return on labor compared to full-sun monocultures. Agronomy for sustainable development, 36(4), 1-10.

[5]Ashenafi, N., Muleta G., Nibret T., 2020, Competitiveness and Yield Advantage of Carrot-Rosemary Intercropping over Solitary at Wondo Genet, Southern Ethiopia, International Journal of Research Studies in Agricultural Sciences, 6(8): 1-9.

[6]Aydınlı, G., Mennan, S., 2018, Brazilian Archives of Biology and Technology Biofumigation Studies by Using Raphanus sativus and Eruca sativa as a Winter Cycle Crops to Control Root-knot Nematodes. Agribus. Biotechnol. 61, 18180249.

[7]Barrena-González, J., Rodrigo-Comino, J., Gyasi-Agyei, Y., Fernández, M.P., Cerdà, A., 2020, Applying the RUSLE and ISUM in the Tierra de Barros Vineyards (Extremadura, Spain) to estimate soil mobilisation rates. Land 9, 93.

[8]Beniaich, A., Silva, M.L.N., Guimarães, D.V., Bispo, D.F.A., Avanzi, J.C., Curi, N., Pio, R., Dondeyne, S., 2020, Assessment of soil erosion in olive orchards (*Olea Europaea* L.) Under cover crops management systems in the tropical region of Brazil. Rev. Bras. Ciênc. Solo, 44.

[9]Bjorkman, M., Hamback, P. A., Ramert, B., 2007, Entomol. Exp. Appl., 124, 319-326.

[10]Bjorkman, M., Hamback, P. A., Hopkins, R. J., Ramert, B., 2010, Agric. Forest Entomol., 12, 123-132.

[11]Blanco-Canqui, H., Ruis, S.J., 2020, Cover crop impacts on soil physical properties: A review. Soil Sci. Soc. Am. J., 84, 1527–1576.

[12]Bomford, M.K., 2004, Yield, pest density and tomato flavor effects of companion planting in garden-scale studies incorporating tomato, basil and brussels sprout (Doctoral dissertation, West Virginia University).

[13]Branzova, P., 2024. New crops: potential and opportunities for the future of agriculture. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 24(3), 107-118.

[14]Broad, S. T., Schellhorn, N. A., Lisson, S. N., Mendham, N. J., Corkrey, R., 2008, Host location and parasitism of Brevicoryne brassicae in diversified broccoli cropping systems. Entomol. Exp. Appl., 129, 166-171.

[15]Bryant, A., Brainard, D. C., Haramoto, E. R., Szendrei, Z., 2013, Cover crops mulch and weed management influence arthropod communities in strip-tilled cabbage, Environ. Entomol., 42, 293-306.

[16]Bryant, A., Coudron, T., Brainard, D., Szendrei, Z., 2014, Cover crop mulches influence biological control of the imported cabbageworm (Pierisrapae L., Lepidoptera: Pieridae) in cabbage, Biol. Control, 73, 75- 83.

[17]Bues, A., Preissel, S., Reckling, M., Zander, P., Kuhlman, T., Topp, K., Watson, C., Lindström, K., Stoddard, F. L., Murphy-Bokern, D., 2013, The environmental role of protein crops in the new common agricultural policy. European Parliament. https://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/495856/IPOL-AGRI_ET(2013)495856_EN.pdf, Accessed on 04.11.2024

[18]Burghilă, C., Bordun, C., Cîmpeanu, S.M., Burghilă, D., Badea, A., 2016, Why mapping ecosystems services is a must in eu biodiversity strategy for 2020?. AgroLife Scientific Journal, 5(2), 28-37.

[19]Cavigelli, M. A., Mirsky, S. B., Teasdale, J. R., Spargo, J. T., Doran, J., 2013, Organic grain cropping systems to enhance ecosystem services. Ren. Agric. Food Syst 28, 145–159.

[20]Cavigelli, M. A., Teasdale, J. R., Conklin, A. E., 2008, Long-term agronomic performance of organic and conventional field crops in the mid-Atlantic region. Agron. J 100, 785–794.

[21]Chapagain, T., Lee, E.A., Raizada, M.N., 2020, The Potential of Multi-Species Mixtures to Diversify Cover Crop Benefits. Sustainability, 12, 2058.

[22]Chen, G., Weil, R.R., 2010, Penetration of cover crop roots through compacted soils. Plant Soil, 331, 31–43.

[23]Chetroiu, R., Ilie, D.M., 2024, Theoretical approach on the nitrogen potential contribution from sustainable natural fertilization with cattle manure. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 24(3), 167-180.

[24]Chu, M., Jagadamma, S., Walker, F.R., Eash, N.S., Buschermohle, M.J., Duncan, L.A., 2017, Effect of Multispecies Cover Crop Mixture on Soil Properties and Crop Yield. Agric. Environ. Lett.2, 170030.

[25]Da Silva Dias J.C., 2010, Impact of improved vegetable cultivars in overcoming food insecurity. Euphytica 176:125–136, doi 10.1007/s10681-010-0237-5.

[26]Damicone, J. P., Edelson, J. P., Sherwood, J. V., Myers, L. D., Motes, J. E., 2007, Plant Dis., 91, 509-516.

[27]Daryanto, S., Fu, B., Wang, L., Jacinthe, P.A., Zhao, W., 2018, Quantitative synthesis on the ecosystem services of cover crops. Earth-Sci. Rev.185, 357–373.

[28]De la Peña, R.C., Ebert, A.W., Gniffke, P., Hanson, P., Symonds, R.C., 2011, Genetic adjustment to changing climates: vegetables. In Crop Adaptation to Climate Change, 1st Ed.

[29]Demir, Z., Işik, D., 2020, The impact of different cover crops, mechanical cultivation and herbicide treatment on the soil quality variables and yield in apple (*Malus domestica* borkh.) orchard with a coarse-textured soil. Tarim Bilim. Derg.26, 452–470.

[30]Depalo, L., Burgio, G., Von Fragstein, P., Kristensen, H.L., Bavec, M., Robačer, M., Campanelli, G., Canali, S., 2016, Impact of living mulch on arthropod fauna: analysis of pest and beneficial dynamics on organic cauliflower (*Brassica oleracea* L. var. botrytis) in different European scenarios, Renewable Agriculture and Food Systems: 32(3), 240–247 doi:10.1017/S1742170516000156.

[31]Dikr, W., Belete, K., 2021, Intercropping of African marigold (*Tagetes erecta* Linnaeus (Asteraceae) Varieties at Different Plant Density with Tomato (*Solanum lycopersicum* Linnaeus) on Yield Related Traits and Yield of tomato at Wondo Genet, Southern Ethiopia, Journal of Biology, Agriculture and Vol.11, No.6.

[32]Dikr, W., 2022, Role of Intercropping some Aromatic and Medicinal Plants with Fruit Vegetables Crops, a Review, Glob. Acad. J. Agri. Biosci, Vol.4(2), pp- 22-30. DOI: 10.36348/gajab.2022.v04i02.002,

[33]Fereres, A., 2000, Barrier crops as a cultural control measure of non-persistently transmitted aphid-borne viruses, Virus Res., 71, 221-231.

[34]Frank, D. L., Liburd, O. E., 2005, Effects of Living and Synthetic Mulch on the Population Dynamics of Whiteflies and Aphids, Their Associated Natural Enemies, and Insect-Transmitted Plant Diseases in Zucchini, Environ. Entomol., 34, 857-865.

[35]Gabriel, J.L., Quemada, M., 2011, Replacing bare fallow with cover crops in a maize cropping system: Yield, N uptake and fertiliser fate. Eur. J. Agron.,34, 133–143.

[36]García-Díaz, A., Marqués, M.J., Sastre, B., Bienes, R., 2018, Labile and stable soil organic carbon and physical improvements using groundcovers in vineyards from central Spain. Sci. Total Environ. 621, 387–397.

[37]Girma, A., 2015, Yield Advantage and Economic Benefit of Maize Basil Intercropping under Different Spatial Arrangements and Nitrogen Rates. Scholarly Journal of Agricultural Science, 5(8): 296-302.

[38]Gomez-Rodriguez, O., Zavaleta-Mejía E., González-Hernández, V.A, Livera-Munoz, M.E., Cárdenas-Soriano, E., 2003, Allelopathy and microclimatic modification of intercropping with marigold on tomato early blight disease development. Field Crop Research, 83: 27-34.

[39]Guardia, G., Aguilera, E., Vallejo, A., Sanz-Cobena, A., Alonso-Ayuso, M., 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.

[40]Hilje, L., Stansly, P. A., 2008, Living ground covers for management of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) and *Tomato yellow mottle virus* (ToYMoV) in Costa Rica, Crop Prot., 27, 10-16.

[41]Hinds, J., Hooks, C. R. R., 2013, Population dynamics of arthropods in a sunn-hemp zucchini interplanting system, Crop Prot. 53, 6-12.

[42]Hooks, C. R. R., Johnson, M. W., 2002, Lepidopteran pest populations and crop yields in row 267 intercropped broccoli, Agric. Forest Entomol., 4, 117-125.

[43]Hooks, C. R. R., Johnson, M. W., 2004, Using undersown clovers as living mulches: effects on yields, lepidopterous pest infestations, and spider densities in a Hawaiian broccoli agroecosystem, Int. J. Pest Mgmt., 50, 115-120.

[44]Hooks, C. R. R., Johnson, M. W., 2006, Population densities of herbivorous lepidopterans in diverse cruciferous cropping habitats: Effects of mixed cropping and using a living mulch, BioCon., 51, 485-506.

[45]Hooks, C. R. R., Johnson, M. W., 2003, Impact of agricultural diversification on the insect 269 community of cruciferous crops, Crop Prot., 22, 223-238.

[46]Hooks, C. R. R., Hinds, J., Zobel, E., Patton, T., 2013a, Impact of crimson clover dying mulch on two eggplant insect herbivores, J. Appl. Entomol., 137, 170-180.

[47]Hooks, C. R. R., Hinds, J., Zobel, E., Patton, T., 2013b, The effects of crimson clover companion planting on eggplant crop growth, yield and insect feeding injury, Int. J. Pest Manage., 59, 287-293.

[48]Hughes, J. d'A., Ebert, A.W., 2013, Research and development of underutilized plant species: the role of vegetables in assuring food and nutritional security. Acta Hortic. 979, 79–91 http://dx.doi.org/10.17660.

[49]Ivanov, B., Krustev, V., Bojinov, B., 2024, Effectiveness and significance of crop yield forecast monitoring constituted on vegetation indices, Scientific

Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 24(3), 457-464.

[50]Jabro, J.D., Allen, B.L., Rand Dangi, S.R., Campbell, J.W., 2021, Effect of Previous Crop Roots on Soil Compaction in 2 Yr Rotations under a No-Tillage System, Land 2021, 10, 202. https://doi.org/10.3390/land10020202.

[51]Jalli, M., Huusela, E., Jalli, H., Kauppi, K., Niemi, M., Hiemanen, S., Jauhiainen, L., 2021, Effects of Crop Rotation on Spring Wheat Yield and Pest Occurrence in Different Tillage Systems: A Multi-Year Experiment in Finnish Growing Conditions, Front. Sustain. Food Syst., Sec. Climate-Smart Food Systems,Vol.5, https://doi.org/10.3389/fsufs.2021.647335.

[52]Jensen, J.L., Thomsen, I.K., Eriksen, J., Christensen, B.T., 2021, Spring barley grown for decades with straw incorporation and cover crops: Effects on crop yields and N uptake. Field Crops Res., 270, 108228.

[53]Jones, G.A., Sieving, K.E., 2006, Intercropping sunflower in organic vegetables to augment bird predators of arthropods. Agriculture, Ecosystems & Environment 117:171–177.

[54]Kaye, J.P., Quemada, M., 2017, Using cover crops to mitigate and adapt to climate change. A review. Agron. Sustain. Dev. 37, 4.

[55]Keatinge, J.D.H., Wang, J.F., Dinssa, F.F., Ebert, A.W., Hughes, J. d'A., Stoilova, T., Ravishankar, M., 2015, Indigenous vegetables worldwide: their importance and future development, Acta Hort. 1102:1-20, DOI:10.17660/ActaHortic.2015.1102.1.

[56]Keesstra, S., Pereira, P., Novara, A., Brevik, E.C., Azorin-Molina, C., Parras-Alcántara, L., Jordán, A., Cerdà, A., 2016, Effects of soil management techniques on soil water erosion in apricot orchards. Sci. Total Environ 551–552, 357–366.

[57]Khafagy, I. F., 2015, The role of some aromatic plants intercropping on Tuta absoluta infestation and the associated predators on tomato. Egy. J. Plant Pro. Res, 3(2), 37-53.

[58]Lal, R., 2004, Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science, 304 (5677), 1623-1627.

[59]Landis, D.A., Wratten, S.D., Gurr, G.M., 2000, Habitat management to conserve natural enemies of arthropod pests in agriculture. Annu. Rev. Entomol. 45:175–201.

[60]Lemke, R. L., Zhong, Z., Campbell, C. A., Zentner, R., 2007, Can pulse crops play a role in mitigating greenhouse gases from North American agriculture? Agronomy Journal, 99(6), 1719–1725.

[61]Lin, B. B., 2011, Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. BioScience, 61(3), 183-193, http://dx.doi.org/10.1525/bio.2011.61.3.4.

[62]Manandhar, R., Hooks, C. R. R., Wright, M. W., 2009, Influence of cover crops and intercrop systems on *Bemisia argentifollii* (Hemiptera: Aleyrodidae) infestation and associated squash silverleaf disorder in zucchini, Environ. Entomol., 38, 442-449.

[63]Manandhar, R., Hooks, C. R. R., 2011, Using protector plants to reduce the incidence of papaya ringspot virus-watermelon strain in zucchini, Environ. Entomol., 40, 391-398.

[64]Marcillo, G.S., Miguez, F.E., 2017, Corn yield response to winter cover crops: An updated meta-analysis. J. Soil Water Conserv. 72, 226–239.

[65]Martínez Raya, A., Durán Zuazo, V.H., Francia Martínez, J.R., 2006, Soil erosion and runoff response to plant-cover strips on semiarid slopes (SE Spain). Land Degrad. Dev.17, 1–11.

[66]Masiunas, J.B., 1998, Production of vegetables using cover crop and living mulches—a review. Journal of Vegetable Crop Production 4:11–31.

[67]Mazzoncini, M., Sapkota, T.B., Barberi, P., Antichi, D., Risaliti R., 2011, Long-term effect of tillage, nitrogen fertilization and cover crops on soil organic carbon and total nitrogen content, Soil and Tillage Research,114(2), https://doi.org/10.1016/j.still.2011.05.001,165-174.

[68]Messinger, J., Lauerer, M., 2015, *Solanum quitoense*, A new greenhouse crop for central Europe: Flowering and fruiting respond to photoperiod. Sci. Hortic., 183, 23–30.

[69]Messinger, J., Martini, M.M.F., Rossi, G., Samuels, J., Lauerer, M., 2015, Successful pollination of the neotropical crop *Solanum quitoense* by Bombus terrestris: Behaviour, efficiency and yield. J. Appl. Entomol., 140(1-2), 124-134.

[70]Midekesa, C., Chala, C., 2022, Productivity of Intercropping with Tomato and Basil under Different Planting Densities at Wondo Genet, Ethiopia, Advances in Life Science and Technology, 9: 19-23.

[71]Mugi-Ngenga, E., Bastiaans, L., Zingore, S., Anten, N.P.R., Giller, K.E., 2022, The role of nitrogen fixation and crop N dynamics on performance and legacy effects of maize-grain legumes intercrops on smallholder farms in Tanzania, European Journal of Agronomy, Volume 141, https://doi.org/10.1016/j.eja.2022.126617.

[72]Mukherjee, R., Sen, S., 2021, Agricultural sustainability through nitrogen fixation: Approaches and techniques. Harvest , 6(1), 48–55.

[73]Neelam, R., Lokho, P., 2009, Intercropping of medicinal and aromatic plants with vegetable cropsareview.MFP News, 19(2): 14-18.

[74]Newton, A.C., Johnson, S.N., Gregory, P.J., 2011, Implications of climate change for diseases, crop yields and food security. Euphytica 179, 3–18 http://dx.doi.org/10.1007/s10681-011-0359-4.

[75]Nigussie, A., Lulie, B., Chala, M., 2017, Intercropping of Onion with Rosemary as Supplementary Income Generation at Wondo Genet Sidama zone, Southern Ethiopia. Acad. Res. J. Agri. Sci. Res., 5(2): 107-115.

[76]Novara, A., Cerda, A., Barone, E., Gristina, L., 2021, Cover crop management and water conservation in vineyard and olive orchards. Soil Tillage Res. 208, 104896.

[77]Paulus, D., Becker, D., Nava, G. A., Luckmann, D., Moura, C. D. A., 2019, Cultivation of mint (*Mentha*

x gracilis) in intercropping with fruit trees in an agroforestry system: Production and quality of essential oil. European J Med Plants, Vol.30 (1).

[78]Piñero, J.C., Manandhar, R., 2015, Effects of increased crop diversity using trap crops, flowering plants, and living mulches on vegetable insect pests. Review, Trends in Entomology Vol. 11, 91-109.

[79]Prohens, J., Rodriguez-Burruezo, A., Nuez, F., 2003, New crops: An alternative for the development of horticulture. Food Agric. Env., 1, 75–79.

[80]Pullaro, T. C., Marino, P. C., Jackson, D. M., Harrison, H. F., Keinath, A. P., 2006, Agric. Ecosyst. Environ., 115, 97- 104.

[81]Quintarelli, V., Radicetti, E., Allevato, E., Stazi, S.R., Haider, G., Abideen, Z., Bibi, S., Jamal, A., Mancinelli, R., 2022, Cover Crops for Sustainable Cropping Systems: A Review, Agriculture, 12(12), 2076; https://doi.org/10.3390/agriculture12122076.

[82]Rodino, S., 2024, Potential of agricultural biomass valorization for circular bioeconomy, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 24(3), 749 - 756.

[83]Rodrigo-Comino, J., Ponsoda-Carreres, M., Salesa, D., Terol, E., Gyasi-Agyei, Y., Cerdà, A., 2020, Soil erosion processes in subtropical plantations (Diospyros kaki) managed under flood irrigation in Eastern Spain. Singap. J. Trop. Geogr. 41, 120–135.

[84]Root, R. B., 1973, Organization of a Plant-Arthropod Association in Simple and Diverse Habitats: The Fauna of Collards (*Brassica Oleracea*), Ecol. Monogr., 43(1), 95- 124.

[85]Ruiz-González, M. X., Vicente, O., 2023, Agrobiodiversity: conservation, threats, challenges, and strategies for the 21st century, AgroLife Scientific Journal – Vol.12(1), 174-185.

[86]Samuels, J., 2015, Biodiversity of Food Species of the Solanaceae Family: A Preliminary Taxonomic Inventory of Subfamily Solanoideae, Resources 4, 277-322; doi:10.3390/resources4020277.

[87]Samuels, J., 2009, The Solanaceae-novel crops with high potential. Org. Grow., 9, 32–34.

[88]Samuels, J., 2014, *Capsicum pubescens*- The Rocoto Pepper: A novel crop Capsicum. Org. Grow., 28, 10–12.

[89]Samuels, J., 2013, Super Fruits. Permaculture 75, 58–61.
https://www.academia.edu/8142181Super_Fruits_Fruiting_Solanaceae_Species_of_Latin_America, Accessed on 04.11.2024

[90]Sans, F.X., Altieri, M.A., 2005, Effects of Intercropping and Fertilization on Weed Abundance, Diversity and Resistance to Invasion. 1st ISOFAR International Conference, Organic ePrints, https://orgprints.org/id/eprint/4468/ Accessed on 28.10.2024.

[91]Scavo, A., Restuccia, A., Lombardo, S., Fontanazza, S., Abbate, C., Pandino, G., Anastasi, U., Onofri, A., Mauromicale, G., 2020, Improving soil health, weed management and nitrogen dynamics by Trifolium subterraneum cover cropping. Agron. Sustain. Dev., 40, 18.

[92]Schipanski, M.E., Barbercheck, M., Douglas, M.R., Finney, D.M., Haider, K., 2014, A framework for evaluating ecosystem services provided by cover crops in agroecosystems. Agric. Syst. 125:12–22.

[93]Stocking Gruver, L., Weil, R.R., Zasada, I.A., Sardanelli, S., Momen, B., 2010, Brassicaceous and rye cover crops altered free-living soil nematode community composition. Appl. Soil Ecol. 45, 1–12.

[94]Stoddard, F. L., Hovinen, S., Kontturi, M., Lindström, K., Nykänen, A., 2009, Legumes in Finnish agriculture: History, present status and future prospects. Agricultural and Food Science, 18(3-4), 191–205

[95]Summers, C. G., Newton, A. S., Mitchell, J. P., Stapleton, J. J., 2010, Population dynamics of arthropods associated with earlyseason tomato plants as influenced by soil surface microenvironment, Crop Prot., 29, 249-254.

[96]Thies, E., 2000, Promising and Underutilized Species, Crops and Breeds. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ): Eschborn, Germany.

[97]Togni, P. H. B., Laumann, R. A., Medeiros, M. A. Sujii, E. R., 2010, Odour masking of tomato volatiles by coriander volatiles in host plant selection of *Bemisia tabaci* biotype B , Entomol. Exp. Appl., 136, 164-173.

[98]Tzemi, D., Rämö, J., Palosuo, T., Peltonen-Sainio, P., Wejberg, H., Lehtonen, H., 2024, The introduction of legume-based crop rotations: an impact assessment on cereal cropping farms in Finland, International Journal of Agricultural Sustainability, 22(1), https://doi.org/10.1080/14735903.2024.2335085.

[99]Waisen, P., Cheng, Z., Sipes, B.S., Wang, K.H., 2022, Biofumigation effects of brassicaceous cover crops on soil health in cucurbit agroecosystems in Hawaii, USA. Pedosphere 32, 521–531.

[100]Wang, Y., Lambers, H., 2020, Root-released organic anions in response to low phosphorus availability: Recent progress, challenges and future perspectives. Plant Soil 447, 135–156.

[101]Watson, C. A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C. F., Vanhatalo, A., 2017, Grain legume production and use in European agricultural systems. Advances in Agronomy, 144, 235–303.

[102]Yigezu, Y. A., El-Shater, T., Boughlala, M., Bishaw, Z., Niane, A. A., Maalouf, F., Degu, W. T., Wery, J., Boutfiras, M., Aw-Hassan, A., 2019, Legume-based rotations have clear economic advantages over cereal monocropping in dry areas. Agronomy for Sustainable Development, 39(6), 58.

[103]Zavaleta-Mejía, E., Gómez, R.O., 1995, Effect of Tagetes erecta L. and Tomato (*Lycopersicon esculentum* Mill). Intercropping on some tomato pests. Fitopatología, 30: 33-45.

[104]Zhao, Q., Zhu, J. J., Qin, Y., Pan, P., Tu, H., Du, W., Zhou, W., Baxendale, F. P., 2014, Reducing whiteflies on cucumber using intercropping with less preferred vegetables, Entomol. Exp. Appl., 150, 19-27.