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VALMEDALM

Deliverable 1.1

Inventory of success and failure factors of intercropping system in almond orchards from Mediterranean regions

VALMEDALM: Valorization of **Med**iterranean **Alm**ond orchards through the use of intercropping integrated strategies

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2. Executive Summary

Intercropping is a practice of growing two or more different crops in the same space with the aim of better exploiting the resources available in the environment. It is a technique that can bring numerous benefits to the soil and plants, and can also generate an alternative income for farmers who only obtain income from perennial crops. The objective of this report is to carry out a bibliographic survey on the main results obtained in intercropping between almond grove and annual crops and the main aspects involved in this practice. Investigation on this subject is limited, however the cultivation of almonds associated with annual crops has shown potential both from an agronomic, ecological and economic point of view.

Key words: perennial crop, annual crop, economic, agronomic, soil-plant.

3. Introduction

During the last centuries, there has been an increase in the world's population, which has led to a change in food production (Tilman et al., 2002). Current agriculture, in order to obtain high yields, has become more industrialized with the excessive use of chemicals (Tilman et al., 2002), with monoculture prevailing, mainly in intensive systems over other agricultural practices, despite this practice resulting in a decrease in biodiversity (Trewavas, 2002), water, climate and health, leading also to soil degradation (Foley et al., 2011; Vermeulen et al., 2012; Steffen et al., 2015; MarqueAssuming., 2020 & Bourke et al., 2021). Due to the known negative effects of monoculture, there are many entities and specialists who demand a change in current agricultural systems to promote an increase in sustainability, food security and avoid irremediable environmental impacts (Tilman et al., 2002; Foley et al., 2011). Taking into account that crop diversity fosters biodiversity and reduces environmental impacts, the agricultural practice of intercropping can promote food security and protect the environment in industrialized and large-scale agriculture (Fung et al., 2019; Rosa-Schleich et al., 2019).

Intercropping is one of the pillars of sustainable agriculture and has been practiced in several countries, due to the need to mitigate the damage caused by conventional methods (Abourayya et al., 2022). The association of different crops will promote the suppression of invasive seeds, pest and disease control, efficient use of water and light, and conservation of available resources (Li et al., 2020). Conceptually, it is a technique for growing two or more crops simultaneously in the same area with the aim of achieving higher yields than in monocultures. The principle of this practice involves the use of species capable of exploiting the existing resources and the environment in different ways, whether in terms of space, light, nutrients, or phenology (Willey, 1990).

In addition to being an alternative source of income, intercropping allows for a better root distribution of species along the field profile, facilitating plant growth in depth and root activity (Abourayya, et al., 2022).

In this sense, the use of leguminous species has been disseminated, taking into account their productive potential and high efficiency in the use of light, water, and nutrients. In addition, its relationship with mycorrhizae favors the development of other species and improves rhizosphere conditions, especially when associated with perennial crops such as fruit trees (Chamkhi et al., 2022).

However, it is necessary to understand that the success of intercropping will depend on how the dynamics of the resources available within the system will be made so that both cultures can perform positive interactions with each other. In addition, there is also the possibility that leguminous plants facilitate other metabolic processes in plants based on their ability to mobilize nitrogen. Another aspect to be discussed is the relationship between the roots of leguminous plants and the microorganisms that normally bring benefits to the rhizosphere and other crops (Duchene et al., 2017; Chamkhi et al., 2022).

There are already several studies published involving intercropping in orchards and the results have been promising. However, we want to highlight the reports that focused on the association between almond trees and other species. Thus, the objective of this work is to review the literature on the main results obtained from the intercropping of almond trees with annual crops and the main aspects involved in this practice.

For this purpose, a bibliographical research was performed for the last decade of work carried out in this area.

4. Success/failure cases of intercropping almonds groves with other crops

Intercropping is a technique that will generate alterations in the soil from the increase of plant material in the rhizosphere, which will allow the improvement of the plant-soil-microorganisms interactions, generating a series of benefits for the plants and improving the soil structure. As for the water in the soil, theoretically, there will be a decrease in surface runoff due to the increase in macrospores in the soil profile (Duchene et al., 2017). According to Chamkhi et al. (2022) soil microbiology is affected by the intercropping of crops, directly impacting the beneficial populations present in the soil. Their study states that the use of legumes in intercrops favors the biological balance and contributes to the indirect control of nematodes and other enemies of crops when they are annual crops. According to Duchene et al. (2017), intercropping plays an important role in root interactions, which are more effective in perennial crops than in annual ones.

In addition to the benefits for the soil, the implementation of an annual crop associated with the orchards contributes to the multiplication of beneficial insects and the attraction of pollinators, which is a very specific need for many fruit species that are self-incompatible, as is the case with most of the almond tree varieties that do not produce without cross-pollination (Company & Gradziel, 2017), although currently there are already self-fertile varieties.

A study conducted in Australia by Saunders et al. (2013) investigated the relationship between wild pollinators and live ground cover in orchards obtaining some interesting data on this subject. According to the authors, the soil cover is capable of interacting with the other elements of the orchard so that pollinator communities can maintain themselves in the long term.

In the case of perennial crops, such as almond grove, associated with annual crops, it is not as common due to competition between species, as according to Castellano-Hinojosa & Strauss (2020), when soil cover is superior to 45% from the canopy of trees, the competition potential increases significantly.

In almond grove, intercropping can be performed at practically any time, from implantation to older orchards. In the implementation of young almond groves, annual crops in soil cover are used as a method of controlling nematodes and sources of organic matter (Company & Gradziel, 2017). From the appearance of the first two leaves of the almond trees, it is possible to start intercropping with the objective of increasing the annual plant biomass, considering that there will be a greater incidence of sun light and, consequently, a considerable amount of green matter. This benefit can be used until the period before the tree crown closes, however, it is necessary to ensure that there is no competition between species (Company & Gradziel, 2017).

In already established or older orchards, the benefits of intercropping will differ according to the objective and the crop used, whether for reasons of soil enrichment or landscape aspects (Eilers & Klein, 2009). It is worth noting that the crop residue cannot interfere with the management and harvesting operations of the almond grove.

According to the study by Abourayya et al. (2022), developed in Egypt, the intercropping of snap bean (*Phaseolus vulgaris* L.) and almond tree (*Prunus amygdalus* B.) had a positive influence on the growth parameters and yield of the leguminous crop. To assess the profitability of production, the relationship between revenue and cost (R/C) is considered and if the result is less than 1, the treatment is not feasible. In the study carried out, intercropping had high profitability, since R/C was equal to 2.03 and the farmer still obtained a net profit on bean production after deducting the cost of maintaining the almond trees. They also verified that the growth characteristics and the constituents of the leaves of young almond trees were superior when the almond tree was

intercropped with the snap bean when compared with the almond trees without intercropping. When the pod is incorporated into the soil, there is an increase in pH and organic carbon content, as well as N, P, K, Ca, and Mg increase in the available levels after 60 days of incorporation when compared to soils where this does not occur.

There are also reports on the cultivation of cereals intercropped with almond trees in semi-arid zones. In this case, the results were positive in terms of land use efficiency and consequent financial return. An important observation was the importance of adequate spacing between the two crops to ensure that there is no photosynthetic limitation of the cover crops or competition for resources between the trees and the other species (Surki et al., 2020). Another suggestion to reduce the influence of the almond tree on light is pruning, a practice that can also benefit its productivity. A further positive effect of the agroforestry system is the increase in the storage of carbon and other nutrients from the sun (Surki et al., 2020).

De Groot et al. (2022) designed an experimental trial in a dry region of southeastern Spain to compare the welfare effects of a multifunctional sustainable land use system with those of an almond tree monoculture applying conventional and sustainable land management practices. The experimental trial included three modalities: monoculture of almond trees with conventional management (mobilization 3-5/year, use of chemical fertilizers and pesticides, without green cover), monoculture of almond trees with sustainable management (using chemical products, fertilizers, and pesticides, with a green cover, composting, and reduced mobilization) and multifunctional (multifunctional use of land with almond trees, cereals, leguminous with the addition of sheep grazing) and concluded that greater financial value is obtained from conventional almond monoculture than in monoculture with sustainable management and in multifunctional use and the economic value was higher in the almond monoculture with sustainable management, followed by the multifunctional system and finally the conventional monoculture.

Despite carrying out an exhaustive search, it was not possible to find studies reporting cases of failure in intercropping almond trees with annual crops.

5. Conclusion

Intercropping has shown to be a promising technique to be incorporated in almond production due to its advantages involving the agrosystem and the economic benefits granted to producers of this nut. However, research work is still very occasional, and more work needs to be developed and disseminated/published so that it is possible to consolidate methodologies to be applied in the different almond-producing regions. On the other hand, it was not possible to find studies reporting that it is not possible to adopt this technique, despite recognizing that there are certain limitations to its application.

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