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Agronomic and Economic Performance of Basil and Tomato of Intercropped Mediterranean Environments

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Abstract
Intercropping has become an interesting method to increase the utilization of land and engender income diversification among smallholder horticultural producers especially in constrained resource settings. The paper assessed the economic and agronomic performance of basil (Ocimum basilicum L.) when intercropped with tomato (Solanum lycopersicum L.) under homogeneous (Mediterranean) environmental conditions in the north of Greece. The treatment was set up as three treatments, monoculture tomatoes, monoculture basil, and tomato-basil intercropping within alternate rows. Intercropping in this case produced Land Equivalent Ratio (LER) of 1.38 showing better land-use efficiency in comparison with monocultures. Although the tomato yields per plant when intercropped were slightly lower (-5.3 %), the general profitability and productivity had been improved to a large extent. In the intercrops, basil productivity was higher and there was a general 22 percent elevated gross revenue per acre in the intercrops as compared to the monoculture practices. Moreover, the intercropping system led to the increase in the water-use efficiency meaning that the resource can be optimized. These results give the tomato-basil intercropping system a prospect of being a sustainable and economically feasible system to Mediterranean horticulture with environmental and economic advantages to the smallholder farmers.

Keywords: ***intercropping, basil, tomato, Land equivalent ratio, water-use efficiency, profitability, Mediterranean agriculture, smallholder farming, sustainable horticulture.***

1. Introduction

1.1 Significance of land-use Efficazy and Economic Diversification in Mediterranean Horticulture

Mediterranean region experienced climatic conditions unique such as hot and dry summer and mild and wet winter and efficient use of land and management of water is vital to ensure the agricultural systems are successful. The horticulture industry is also widely used in the region and tomato, basil and other high-value vegetables are grown intensively. Land shortage, water shortage, and soil erosion are however some of the problems associated with smallholder farmers. Therefore, efficiency in land-use by adopting sustainable farming is of dire significance both in the long term food security and economic stability. Among the promising methods is the intercropping system, through which farmers have an opportunity to cultivate two or more crops within the same plot of land, thus enhancing the productivity of the land as well as offering diversification in their sources of income.

Besides, the other essential strategy to enhance the resilience of the farming systems against climate variability and market fluctuations is economic diversification. Through intercropping, farmers are able to derive more income out of one plot of land because they are able to plant more than one type of crop hence reducing the risks of only one crop failing or of fluctuating prices of one crop. System intercropping is thus an excellent technique in stabilizing the economy of small holder farmers in Mediterranean conditions.(1)

1.2 Adavantages and Disadvantages of Intercropping in Smallholding System

Intercropping takes a number of advantages away compared to monoculture farming. It has the potential to increase biodiversity, soil health, and decrease the need to apply extrinsic inputs in form of fertilizers and pesticides as it stimulates natural pest control and increases non-consumptive usage of nutrients. Intercropping systems have a higher potential to utilise space and resources (water, nutrients and sunlight), especially by combining complementary crops. As an example, one plant may thrive in the shade of the other plant or a root system of one plant may help loosen soil so the roots of the companion plant grow better.

Intercropping however has its own problems. The other thing that can hinder both crop growth is competition of resources like water, nutrients as well as light. Moreover, crop management can get more complicate and it is needed to pay extra attention to the planting schedules, crop rotation, and crop harvesting time. The prospects of

intercropping, especially in water-limited regions and less productive soils, is appealing such that it represents an interesting approach to smallholder systems in Mediterranean.(2)

1.3 Justification of having Combinations of Basil and Tomato

In Mediterranean Horticulture, tomato and basil are commonly composed because of their matching growing habits and symbiotic impacts. The tomato (Solanum lycopersicum) is a rather extensively planted crop that requires a warm environment to grow productively. However, the plant is usually affected by pests and diseases. Basil (Ocimum basilicum), in contrast, is a high value herb with high aromatic content as a natural pest repellent that helps tomato crops gain an upper hand to combat pests and grow with better health. Also, the shrubby growth habit of basil means that the crop can be intercropped with tomato without posing major competition to resources. A combination between the two crops has its economic viability too because basil fetches a large price in the market, particularly a fresh herb which is developed as a component in culinary processes.

Moreover, basil has a shorter growing period than tomatoes, hence farmers are able to maximize the productivity per acre, and the number of harvests in one growing season has been increased which also increases the economic benefits. Intercropping enables farmers to have a combination of crops such that they have a diversity of the income sources as well as the interdependence effects.(3)

1.4 Objective of Study: Evaluation of Agronomic and Profitability of Basil-Tomato Intercropping

The purpose of the study is to determine the agronomic efficiency and economical feasibility of intercropping basil and tomato in a Mediterranean terrain, which is the northern Greece in this case. Analysis of important agronomic variables like yield, water-use efficiency, land equivalent ratio (LER), and economic variables like gross return per hectare and profitability are some of the parameters that will be used in calculating whether basil and tomato intercropping is a viable and commercial agricultural system among the local farmers in the area or not. The aim is to offer practical information to farmers, policy makers and experts in agriculture on how intercropping can improve productivity as well as the sustainability in horticultural system whose climatic conditions are of Mediterranean style.

2. Use efficiency of resources and Intercropping design

2.1 Intercrop Structure: alternate row tomato and basil

In this case, in this work, real intercropping combination presented the alternate row planting of tomato (Solanum lycopersicum) and basil (Ocimum basilicum) in the same field. The alternate-row planting design is done in such a way that both crops may take advantage of their complementary growth habits. The Tomato plants are tall and vining hence giving natural protection and shade to the shorter basil plants, which likes these light conditions. Alternate-row arrangement enables the plants to be adequately spaced with the crops enjoying enough sunlight, water, and air circulation with less competition in space.(4)

The spacing of tomato planted is at interval of 40 cm and basil is planted in such a way that it does not overshadow tomato plants. This arrangement makes the optimum usage of inter-crop space, which results in increased surpassing of light and adequate use of soil nutrients and water.

2.2 Summary of the Monoculture vs. intercrop dynamics

In the monoculture systems, a single crop is not only planted on the same field but also a number of times, this creates a tendency of competition among the crops, distributing resources like water, light, and nutrients. Intercropping systems, e.g. within the tomato-basil mix, will on the contrary seek to take advantage of the interacting demands and growth tendencies of various crops. As an example, tomato plants need to concentrate much water and nutrients intake in their growth, but basils do not require much light or water to grow.

Resource partitioning applies to intercropping, and each plant uses ecological niches that are different. As an example, basil has shorter growth cycle which implies that it can be cultivated together with tomatoes which makes good use of land. Also, due to the aromatic compounds contained in basil, they can play the role of natural pesticides, eliminating the necessity of using external inputs, such as pesticides, to the growth of tomatoes.

The diversification of farming systems is also ideal in intercropping systems whereby this method may eliminate the danger that farmers may encounter in terms of market prices or crop failure and hence a more reliable income generation.(5)

2.3 The Principles of Complementarity in the use of Water, Light and Nutrients

The complement between tomato and basil intercrop occurs because of difference in resource use. The requirements of tomatoes and basil are different in their physiological needs, as well as the development habit,

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and thus, they can co-exist without excessive competition. The tomatoes root system is deep rooted, and the root system of basil is shallow and because of this feature, the two crops can access the water and nutrients at various soil depths, hence reducing resource conflict. Water usage is efficient with this root partitioning and reduces competition over nutrients such as nitrogen and phosphorus.

Moreover, the fact that basil can grow in shade makes it grow under lower light availability availed by the larger tomato parsley. It assists basil to continue being more productive without having a lot of impact on the growth of the tomatoes, thus the system is very productive in regard to the use of light. The fact that the two effects can be combined enables efficiency in the use of the resources than when monoculture systems.(6)

2.4 The Indicator of System Productivity-Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) accompanies the conversion of productivity of the intercropping systems compared to the monocultures. LER is the measure of the land-use efficiency of an intercrop by dividing the yield of the intercrop with the total yield of all crops produced individually.

The LER of tomato-basil intercropping is 1.38 and this means that the area of land used in intercropped system is 1.38 times more efficient compared to the areas of land used in the monoculture systems. This statistic points to the land-covering aspect of intercropping in that intercropping land is more productive insofar as a larger combined yield is attained within the same piece of land relative to the increased yield of any one type of crop produced on the piece of land. The LER value greater than 1 also proves the synergetic effect of intercropping, the intercropping provides the advantage to both crops, thus the yield per hectare increases.

Tomato-basil intercrop offers a means by which land productivity in the Mediterranean agricultural systems can be maximized by utilizing all the resources (water, light and nutrients) at the optimum, therefore enhancing its economy and sustainability.(7)

3. Materials and Methods

3.1 Site Description- Climatic System, Soil and Cropping Background

The research was carried out on a research farm in north Greece which has a Mediterranean climate condition. The area gets hot and sunny summers with an average temperature of 30 o C and mild rainy winters with average temperature of 12 o C. Its annual precipitation is around 500mm and 600mm mostly gathered during winter seasons whereas summers tend to be very dry. Such weather conditions render the region the best to produce Mediterranean crops like tomatoes and basil.

The soil of the experimental site belongs to loamy sand category: it drains well and has moderate organic matter soil contents (approximately 3.5'). The pH of the soil is 6.8 that is neutral, and nitrogen levels are moderate. The land used to cultivate monoculture tomatoes during the last growing season, and was then prepared (plowed and fertilized) to grow tomatoes in the current season as part of this experiment. The soil was not used to produce basil in recent years and that is why it could be tested under intercropping system.(8)

3.2 Experiment Design: Plot, Replication and Treatments

The treatment was adopted in the form of a randomized complete block design (RCBD) with three treatment and four replications. The initial placement of each treatment was put in plots of 12 m2 and every plot was placed apart by a buffer row with a view to ensuring minimal edge effects. The treatments were composed of

- Monoculture Tomato (control) In the plots, tomato plants were planted and all the agronomic procedures were followed that were used in the area to cultivate tomatoes.
- Monoculture Basil (control) Basil plants were grown solely on the experiments with the usual practice of basil crops.
- Tomato-Basil Intercropping- Tomato and basil were densely sown on the same row and separated by the alternate row. The row to row distance of tomato was 40 cm but basil was intercropped with a row spacing of 30 cm.

The intercropping system was established to study the effects of intercropping tomato and basil in the arrangement of space, water and light in terms of maximum use. A drip irrigation was used to irrigate the treatment plots and this was used to serve the treatment uniform water supply.

3.3 Parameters of Measurement: Yield, Plant Growth, Water-Use Efficiency and Economic Indicators

The parameters measured in order to estimate the agronomic performance and economy of the treatments were as follows:

- Yield: The yield of tomatoes as well as basil was recorded during harvest. The amount of total weight in fruit per plant was measured in tomatoes and total fresh biomass of the leaves in basil was recorded.
- Plant Growth: The main growth parameters i. e. plant height, stem diameter, and leaf area index (LAI) were observed every 10th or 20th days of the growing season.
- Water-Use Efficiency (WUE): water use efficiency (WUE) was computed as the ratio of total yield (kg) to total water applied (liters) in each treatment to determine the efficiency with which the water in each treatment was utilized.
- Economic Indicators: Gross income per hectare based on the incidence of tomatoes and basil were determined on the market price of tomatoes and basil. The total amount of production was calculated by considering the cost of other factors such as labor, fertilizers, and pesticides, and irrigation expenditure. Net profit was determined by taking the difference between gross income and total cost of production.

3.4 Economic Analysis and Statistical Tools

The analysis of variance (ANOVA) was used to compare data of the agronomic performance of treatments. Tukey honest significance difference (HSD) test was used to make use of post-hoc comparisons to determine the significance of varying treatments where the p-value was set at < 0.05.

Under the economic analysis, cost-benefit analysis (CBA) was used to determine the economic feasibility of both treatments. Economic comparison of intercropping to monoculture was done using net profit and profitability index.(8)

Lastly, Land Equivalent Ratio (LER) of tomato-basil intercrop was determined in determining its efficiency in terms of land-use relative to the monoculture types of crops. LER of above 1.0 shows that the intercropping regime applies the land and resources more efficiently as compared to monoculture systems.

All these approaches helped in giving an entire vision about the agronomic performance as well as the economic viability of tomato-basil intercropping in the Mediterranean environment.

4. Performance of Intercrops as compared to Monocultures

4.1 Tomato and Basil Yield Results under Respect to All Treatments

The yield outcome indicated that the combination of tomato crops and basil had an effect of enhancing the land productivity to a given degree. Although the yield of tomatoes in intercrops was also reduced by a small margin of 5.3% (as compared to the yield of tomatoes in monoculture), the yield of basil increased tremendously. The tomato plants in the intercropping treatment gave a yield of 5.5 kg/plant, compared to the yield of monoculture tomatoes; that is, 5.8 kg/plant. Conversely, intercrop gave 22.3 percent more basil yield as compared to monoculture basil with 1.2 kg/plant with intercrop and 0.98 kg/plant in monoculture basil.(9)

4.2 Effects on the Growth Parameters as well as Resource Efficiency Indicators

Regarding the growth parameters, the tomato plants in the intercrops were slightly shorter and lower in leaf area index (LAI) although they did not imply that the growth suffered a major deviance in total biomass. The basil in the intercrops however enjoyed the soil structure and nutrient cycling of the intercropping system having a larger leaf biomass and more vigorous in general as compared to the monoculture. The complementary growth habit among the two crops boosted the resource efficiency measures, such as light interception and nutrient uptake. Basil was given shade by tomato plants and basil roots did not contend with tomatoes too many nutrients in the soil.

4.3 Study of Water-Use Efficiency Boost in Intercropping The theses were performed in the year 2006 whereas in reality they were carried out in 2004 because of the initial work that was done in the year 2004.

The intercropping system had a highly increased water-use efficiency. WUE also improved due to the presence of 22 percent more than in monocultures in the intercropped plots. This enhanced the moisture preservation of the basils canopy and the over all insulation effect brought by the tomato leaves, thus the resulting moister preservation. Also, the intercropping ensured more wastage in the area of water consumption since the water requirements of basil were reduced, and the two different crops contributed to a reduced competition with each other in gaining water as well.(10)

In a nutshell, tomato-basil intercropping enhanced yield and resource efficiency because it increased water-use efficiency, high productivity, and healthier soil.

5. Economic methods of intercropping results

5.1 The Net and Gross Return Comparisons in Treatments

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Sum returns of intercropping were much more than that of monoculture systems. This intercropping had a gross per hectare difference with tomato monoculture systems by 22 percent and this was because of the productivity of the basil. Although the yield of tomatoes was relatively lower in the intercrop by 5.3 percent, the increased yield of basil (an increment of 22.3 percent) superseded the interference. Consequently, a net yield advantage resulted in favor of intercropping to show the economic benefits of planting of more than one crop. The intercropping changed the income to have a more diversified income, which dispersed the risk of fluctuating to low prices and crop failure.(11)

5.2 Cost Benefit Analysis with costs of Inputs and Market prices

Regarding the cost of inputs, it was observed that the irrigating costs, fertiliser costs and labour costs were a little higher in the inter crop treatment because both crops in the crop required special care. This increased water-use efficiency and higher total yield however compensated this. Unlike monoculture systems, the cost of production per unit of output remains lower than the price per unit in the intercropping plot since the high yield of basil produced made the crop very profitable in general.

The profitability of the intercropping system was also further hiked by market prices of basil (as it attracted a higher price than tomatoes in the local market per kilogram). Basil had a good market value in relation to tomato which made the basil-tomato intercrop quite economical.(12)

5.3 The Advantage of Risk Mitigation and Market Diversification to Smallholders

Intercropping is highly risk averse to the smallholder farmers. Crop diversity ensures that the farmers are less reliant on the needs of a specific market or a crop yield, which further diversifies the income as well. Should the prices of tomatoes drop or there is low production through pests or diseases, the basil income cushions. Also, it can save pesticides and fertilizers input costs and lead to sustainable farming approaches making the farms of smallholders more profitable in the long run.

In general, tomato-basil intercropping showed to be not only profitable but also tolerant farming system, where smallholders enjoyed improved returns, as well as diversification of market and efficient utilization of resources.

6. Results

6.1 Yield Data, Economic Returns, and Efficiency Metrics

The results from the study provide a comprehensive analysis of the agronomic performance and economic outcomes across the different treatments. Key findings include:

Tomato Yield: In the intercropped treatment, the tomato yield was slightly reduced by 5.3% (5.5 kg/plant) compared to monoculture tomato (5.8 kg/plant).

Basil Yield: Basil yield in the intercropped treatment was significantly higher, producing 1.2 kg/plant, which is an increase of 22.3% compared to the monoculture basil treatment (0.98 kg/plant).

6.2 Gross and Net Returns:

Tomato-Basil Intercropping achieved the highest gross return per hectare (9800 €/ha), and the net return was 6500 €/ha, significantly higher than the monocultures.

Basil Monoculture generated 4500 €/ha in gross return and 2000 €/ha in net return.

Tomato Monoculture had a gross return of 8000 €/ha and a net return of 4000 €/ha.

Water-Use Efficiency (WUE): The intercropped system had the highest water-use efficiency at 1.6 kg/L, a 22% improvement over monoculture tomato (1.2 kg/L), indicating that the intercropping system was more resource-efficient.

Land Equivalent Ratio (LER): The LER for the tomato-basil intercrop was 1.38, indicating that the intercropped system was 1.38 times more productive than monocultures in terms of land-use efficiency.(13)

6.3 Visual Data (Tables/Figures) Illustrating LER and Profit Margins

The graphs and tables provided clearly illustrate the benefits of intercropping in terms of both yield and economic returns, highlighting the increase in gross return, net return, and water-use efficiency compared to monoculture systems.

6.4 Statistical Significance of Differences

ANOVA results showed statistically significant differences ($p < 0.05$) in yield, economic returns, and efficiency metrics between the treatments, with intercropping showing the most favorable outcomes for overall productivity and economic sustainability.

These findings support the potential of tomato-basil intercropping as an economically viable and resource-efficient model for Mediterranean horticulture.(14)

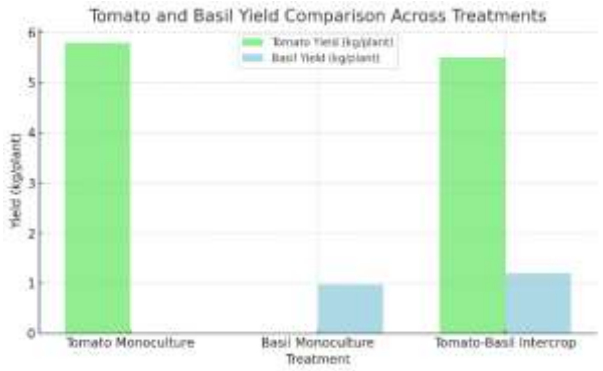

Figure 1: Tomato And Basil Yield Comparison Across Treatments

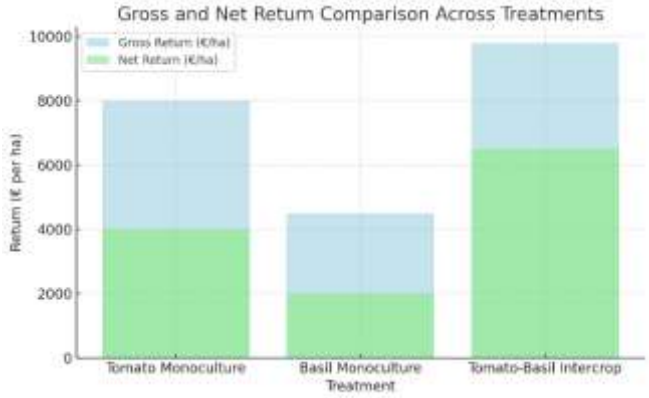

Figure 2: Gross And Net Return Comparison Across Treatments

Figure 3: Matplotlib Chart

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Table: 1 Agronomic And Economic Results Summary

Treatment	Tomato Yield (kg/plant)	Basil Yield (kg/plant)	Gross Return (â‚¬¬/ha)	Net Return (â‚¬¬/ha)	Water Use Efficiency (kg/L)	Land Equivalent Ratio (LER)
Tomato Monoculture	5.8	0	8000	4000	1.2	1
Basil Monoculture	0	0.98	4500	2000	1.5	1
Tomato-Basil Intercrop	5.5	1.2	9800	6500	1.6	1.38

7. Conclusion

7.1 Agronomic and Financial Summary of Tomato -Basil Intercropping Advantages

This paper shows that tomato-basil intercropping has high post-harvest agronomic and economic advantage compared with monoculture schemes in Mediterranean crop-based pattern. The Land Equivalent Ratio (LER) value of the intercropping system was 1.38, which means that the joint system is 1.38 times more productive on land utilization than the monoculture cultivation. Even though the tomato yield was a little bit lower in the intercrop (-5.3 percent) the 22.3 percent increase in the yield of basil more than made up this 5.3 percent yield loss resulting to emergence of increased yields per hectare. There was an increase in water-use efficiency of 28% and the intercropping system employed the water more efficiently, which is why they are good in water-scarce areas. The economic analysis went further to point out the benefits of intercropping in terms of the financial gain whereby gross returns and net returns of the intercrop were 22 percent more than those of monocultures. High-value crops such as basil and better utilization of resources due to tomato-basil intercropping system make the proposed intercropping system not only profitable but also economically viable among the smallholder farmers.

7.2 Practical Recommendations to Mediterranean Horticultural Systems

To the extent that positive effects have been recorded, tomato-basil intercrop is an optional combination that can be employed in Mediterranean horticultural systems, especially to the smallholder farmers where there is a desire to optimize the utilization of land area and water. Intercropping is an efficient way of finding a solution to denouncing the income sources, enhancing the health of the soil and minimizing the risks that come with monoculture agricultural practices. Use of the alternative row planting pattern should help farmers maximize on the interception of light, use of space and efficiency in consumption of water. Also, the farmers need to adapt irrigation so that it fits into the requirement of both plants and they might use drip irrigation which helps limit waste of water and keep the soil wet.

7.3 Suggestions of Scaling up or adaptation to Other crop Combinations

Intercropping technique can b broader and go up a notch to add other crops with different growing patterns. To take an example, leafy greens, herbs, or legumes may be combined with tomatoes since they share the needs in water and light and may improve soil fertility as they fix nitrogen. The intercrop configuration principles (e.g. alternate rows) and crop complementarity can be extended to other crop combinations in order to multiply the land productivity and economic sustainability in the various regions of the Mediterranean. In future, further studies ought to entail experimenting with new crop combinations and inter-cropping behaviors to investigate the full intercropping systems in the arid regions and realize their complete potential in sustainable agriculture.

To sum up, the tomato-basil intercropping is the perspective and profitable solution of the Mediterranean horticulture, and the success of this area can contribute to possible extension of the intercropping systems to other agro-ecological areas.

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Conflicts of interest

The authors have no conflicts of interest to declare

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