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International Journal of Innovations in Science & Technology
RESEARCH & INNOVATION DIVISION
IJIST

Agroforestry Potential and Analysis of Growth and Yield of different Vegetables Grown Under Olive Orchard to Mitigate Climate Change Effects

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Citation | Kausar. R, Ehsan. S, Jilani. G, Nain. Q, "Agroforestry Potential and Analysis of Growth and Yield of different Vegetables Grown Under Olive Orchard to Mitigate Climate Change Effects", IJIST, Special Issue pp 685-700, July 2024
Received| June 23, 2024 **Revised|** June 29, 2024 **Accepted|** July 06, 2024 **Published|** July 09, 2024.

Olive is a drought-tolerant plant, making it suitable for cultivation in various dry regions of Pakistan. By applying the principles and regulations of agroforestry, we can increase crop yields, thereby creating a self-sustained farming ecosystem. Agroforestry is a technique that integrates the production of trees, vegetation, and livestock on the same land to achieve financial, environmental, ecological, and cultural benefits. A field experiment was conducted on six winter vegetables—cabbage, Chinese cabbage, kohlrabi, leafy green lettuce, leafy red lettuce, and broccoli—grown under three olive orchards of different ages (10, 20, and 30 years) with varying shading capacities at the Horticultural Research Institute, National Agricultural Research Center, Islamabad. The study focused on intercropping vegetables within olive orchards of different ages. Critical parameters were monitored, and strict plant inspections were carried out during the experimentation period. Plant samples were tested for morphology and chemical composition. It was found that more vigorous olive trees significantly decreased the growth, leaf chlorophyll content, nutrient uptake, and yield of the intercropped vegetables. Maximum shading from the 30-year-old olive orchard severely reduced plant growth and yield. The extent to which growth is limited by intercropping or shade intensity may vary with the genetic makeup of different crops. The results showed that plants grown under optimal light conditions exhibited greater plant height, spread, and stem diameter, attributed to the stimulation of cellular expansion and cell division under adequate sunlight, which increases photosynthetic efficiency. Cabbage and kohlrabi were identified as the most viable crops under the experimental conditions.

Keywords: Agroforestry, Olive Orchard, Lettuce and Kohlrabi.

Introduction:

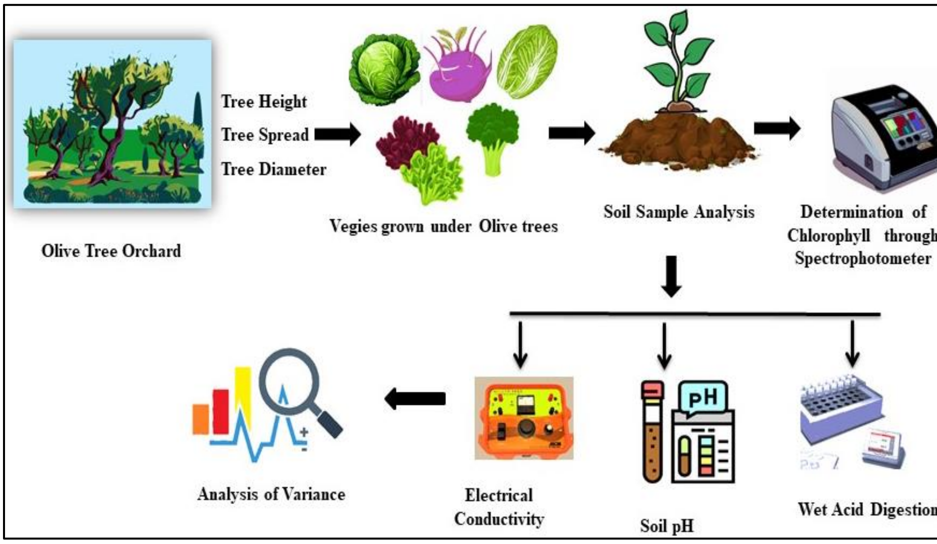

Figure 1: Lay out of the research study

Introduction:

Agroforestry is an agricultural practice that involves creating self-sustained land-use systems, which significantly impact both the modern environment and economy [1]. It serves as an alternative approach to land conservation and supports sustainable farming by establishing a self-sustained ecosystem [2]. Historically, the practice of cultivating trees and crops together has been common across the globe, with trees playing a vital role in terrestrial ecosystems by providing essential products and services to human communities worldwide.

For decades, agroforestry practices have been promoted in both tropical and temperate regions due to their numerous benefits, including soil quality improvement and other ecosystem services [3]. While soil quality is a concern in both natural and managed ecosystems, soil health is particularly emphasized in managed agroecosystems [4]. Agroforestry operates as a natural system that ensures the sustainable protection of soil and the atmosphere. The careful selection of crops, planting rates, and sowing arrangements in agroforestry systems helps reduce competition among plants. However, varying crop combinations may affect yield due to different requirements for water, light, and soil nutrients. Yield advantage is achieved when growth resources are effectively absorbed and converted into crop biomass over time.

New techniques and procedures are continuously reevaluated for their benefits in agroforestry. Since crop productivity is constrained by resource availability and depends on how efficiently a crop utilizes these resources, species within an intercropping system should possess contrasting agrobotanical traits. These traits include size, growth patterns, physical properties, lifecycle, production, nutrient demand, and light intensity requirements [5]. Proper intercropping cultivation can maximize crop growth and productivity [6], enhance resource use efficiency [7], and increase microbial diversity [8]. Intercropping also helps balance nutrient levels in the soil [9], reduces pest and disease damage [10], and improves both the quantity [11] and quality of agricultural products [12].

In tropical regions, fruits and vegetables are essential for both food security and income generation for small-scale farmers. These high-value crops are integral to home garden agroforestry systems, where they contribute to biological stability, enhance crop diversity, conserve soil properties, and boost overall productivity. The horticulture sector plays a critical role in improving land productivity, creating employment, enhancing farmers' livelihoods, increasing exports, and ensuring dietary protection [13].

Among the promising investments in agroforestry is the olive tree [6], the only member of the Oleaceae family cultivated for edible purposes. Olive trees have a high survival rate in harsh environments, such as drought and semi-arid conditions. Olive oil, a significant product of the olive tree, is free of cholesterol, making it one of the healthiest oils for human consumption. It is widely used for cooking, industrial lubrication, and in the cosmetics industry. Olive oil, which contains 75% oleic acid, is also valued for its dietary and medicinal benefits. The significance of the olive fruit is highlighted in religious texts such as the Holy Quran and through the sayings of the Holy Prophet.

The introduction of olives to the Pakistani market was initiated by the Pakistan Agricultural Research Council (PARC) in 1986 under the "Fruit, Vegetable, and Olive Project," funded by the Italian government. During this project, a survey estimated the presence of approximately eighty million wild olive plants [14] across various districts in Pakistan. Another federal government project aimed to plant around five million olive trees, but the survival rate was less than 1%. Currently, the "Promotion of Olive Cultivation for Economic Development and Poverty Alleviation" project, funded by the Italian government under the Debt Swap Agreement, is operational under PARC, in collaboration with provincial and local bodies.

Vegetable-based agroforestry (VAF) systems have shown better productivity, increased fertilizer use efficiency (FUE), higher profitability, and enhanced environmental services compared to monoculture vegetable systems. Over 35 types of vegetables are cultivated across different ecosystems in Pakistan, ranging from dry to wet zones, low to high elevations, rain-fed to irrigated areas, and low-input to high-input systems, such as plastic houses. During the summer and spring, crops like tomatoes, chilies, brinjals, potatoes, cucumbers, gourds, and okra are commonly grown. The rainy season favors crops such as gourds, cucumbers, beans, okra, and brinjals. The winter season is vital for growing a wide variety of vegetables, including cauliflower, cabbage, lettuce, spinach, onion, potato, carrot, radish, turnip, coriander, fenugreek, and peas. Vegetables produced in different zones using various production technologies during different seasons are traded across Pakistan to meet consumer demand. The diverse agro-climatic conditions in different provinces enable year-round vegetable production, ensuring market availability throughout the year.

While the benefits of integrating high-value crops into agroforestry systems are recognized, few studies have quantified and described tree-crop interactions. This research aims to address the productivity, profitability, nutrient use efficiency, and environmental services of different vegetables in olive orchards. Field experiments were conducted to evaluate six different vegetables in three olive orchards. Crop growth and yield data were collected relative to tree age to determine productivity, adaptability, and competition. The objectives of this study are:

- To identify the best-suited vegetables for intercropping with olive orchards.
- To conduct a cost-benefit analysis of olive orchards with vegetable intercropping.

Materials and Methodology:

A field experiment was conducted in 2019 on six winter vegetables—cabbage, Chinese cabbage, kohlrabi, leafy green lettuce, leafy red lettuce, and broccoli—grown under three olive orchards (25, 30, and 35 years old) with different shading capacities at the National Agricultural Research Center (NARC), Islamabad, Pakistan. The goals of this study were to determine the importance of the association between olive trees and vegetable crops and to estimate the productivity of this association.

Geographical Location:

The experimental site is located at 73.08°E longitude and 33.42°N latitude, with an elevation of 683 meters above sea level.

Climatic Conditions:

Data on mean diurnal temperature and mean rainfall for the entire cropping period were obtained from the Water Resources Research Institute, NARC, Islamabad, Pakistan (Table 2). The average monthly temperature varied, with higher temperatures observed in certain months and lower temperatures in others. In contrast, total monthly rainfall was higher in March and June but lower in May. Rainfall during the growth period was approximately 264 mm, 231 mm, 182 mm, 248 mm, and 344 mm, respectively..

Table 1: Climatic condition of site during experimentation (2018-19)

Months	Maximum temperature (°C)	Minimum. temperature (°C)	Relative humidity (%)	Rainfall (mm)
October,2018	29.03	13.29	59	45.63
November, 2018	24.07	8.33	63	21.71
December, 2018	19.61	3.13	66	28.05
January, 2019	15.74	3.45	75	144.58
February, 2019	17.93	6.39	77	94.00
March, 2019	22.23	8.84	69	49.48

Source: Water Resources Research Institute, National Agricultural Research Center, Islamabad, Pakistan.

Experiment Site:

Table 2 presents an analysis of soil samples (1-12 inches) taken from the field shortly before planting. The soil analysis indicated that the soil was relatively rich in plant nutrients, with the upper surface having higher nutrient content compared to the subsurface, likely due to the regular application of manure and fertilizers.

Table 2: Soil characteristics of three Olive orchard (experimental sites) before fertilizer application

Parameters	Open Field	Orchard I	Orchard II	Orchard III
Texture	Loam	Loam	Loam	Loam
PH	7.4	7.4	7.4	7.4
EC	0.45 dS m-1.	0.45 dS m-1.	0.45 dS m-1.	0.45 dS m-1.
N	0.038 mg kg-1	0.036 mg kg-1	0.038 mg kg-1	0.036 mg kg-1
P	7.07 mg kg-1	6.8 mg kg-1	6.4 mg kg-1	6.8 mg kg-1
K	120 mg kg-1	100 mg kg-1	100 mg kg-1	100 mg kg-1

The bulk density of representative soil samples was 1.40 g/cm³ (0-15 cm) and 1.45 g/cm³ (15-30 cm) with a field capacity of 13%. The permanent wilting point of the samples was 5%, and the available soil moisture was 8%.

Plant Material:

Olive Orchards:

Table 3: Olive Orchid Data

Orchard	Variety	Age in years	Source	Average plant Height (ft)	Average plant spread (ft)	Average trunk diameter (ft)	Plant to plant space (ft)
I	Gamlick	10	Turkey	14	26	3	10
II	Gamlick	25	Turkey	15	30	4	12
III	Gamlick	30	Turkey	16	30	4	15

Vegetables:

Table 4: Vegetable Data

S.No	Crop	Genotype	Source
1	Cabbage	Golden Acre	Aurius Califorina
2	Chinese Cabbage	Blues	Takii Kyoto japan
3	Kohlrabi	Express forcer	Takii Kyoto japan
4	lettuce	Green wave	Takii Kyoto japan
5	Lettuce leafy (Leafy red)	New Red fire	Takii Kyoto japan
6	Broccoli	Marathon	Sakata seed japan

Experimental Details:

A research methodology was established to validate our experimental results in the future and compare them with various other studies. The selection of local crops was based on regional demand and different cultivation regimes, ultimately leading to the selection of six plants with year-round demand. Olive orchards were chosen to assess the impact on running costs.

Cultivation:

Seeds of the six selected crops were sown in trays of multi-pots filled with an equal mixture of sand, soil, and decomposed manure. The seeds were planted in August for the field experiment.

Field Preparation and Common Treatments:

The farm field was meticulously prepared by ploughing three times using a disc harrow, followed by re-leveling to ensure proper drainage. Organic manure was applied at a rate of 20 t/ha, along with chemical fertilizers at 55 kg/ha of nitrogen (N), 80 kg/ha of phosphorus (P), and 32 kg/ha of potassium (K) in the form of urea. A randomized complete block design (RCBD) was employed for transplanting the six crop nurseries after 45 days. Each treatment was conducted on a gross plot size of 2.5 x 3.0 meters, with twenty plants per plot. The plant grid featured rows spaced 75 cm apart and plants spaced 50 cm apart. Fertilizers and irrigation were distributed evenly across all plots to ensure uniform crop growth.

Experimental Data Collection:

Data were recorded for various parameters, including morphological, biochemical, and yield attributes. Samples were collected from each labeled crop, with no fewer than three samples taken 75 days after transplantation. The average of three plants was used for analysis. The recorded attributes and characteristics are as follows:

Olive:

- **Tree Height (cm):** The average tree height was measured on a per-tree basis and recorded in centimeters.
- **Diameter of Tree Stem (cm):** The average tree stem diameter was measured on a per-tree basis and recorded in centimeters.
- **Tree Spread (cm):** The average horizontal spread of the tree was measured on a per-tree basis and recorded in centimeters.

Vegetables:

- **Plant Height (cm):** Height was measured from the stem base to the shoot tip 75 days after transplantation. The sample size was two plants, and the mean height was recorded in centimeters.
- **Plant Spread (cm):** The average horizontal spread of the plants was measured 75 days after transplantation and recorded in centimeters.

- **Total Dry Matter per Plant (g):** A sample size of two plants per genotype for each replication was used. The plants were dried in a hot air oven at 80°C for approximately 72 hours until a constant weight was obtained. The dry weight was recorded 75 days after transplantation and expressed in grams per plant.
- **Plant Yield (kg):** The fresh weight of cabbage, Chinese cabbage, kohlrabi, leafy green lettuce, leafy red lettuce, and broccoli harvested from three tagged plants was recorded. The total yield per plant was calculated and recorded in kilograms per plant.
- **Determination of Chlorophyll a and b:** Following the method of Lichtenthaler (1987), powdered leaves from six selected vegetable samples were standardized in 80% acetone and filtered through Whatman paper. Chlorophyll a, b, and total chlorophyll were estimated using a spectrophotometer, with absorbance measured at wavelengths of 663, 645, and 652 nm, respectively.

Physio-Chemical Analysis of Soil:

Standard methods were used to assess the following physical and chemical properties before the experiments:

- **Soil Texture:** A sample of 40 g of air-dried soil was stirred with 60 ml of dispersing solution and left overnight. The sample was then mixed with water and stirred continuously, with readings taken using a hydrometer, according to Day (1965).
- **Soil pH:** A sample of 5 g of air-dried soil was mixed with 50 ml of distilled water and stirred for an hour. The pH was recorded using a pH meter.
- **Electrical Conductivity (EC):** The soil sample was mixed with water and incubated for an hour. The conductivity of the extracted solution was determined according to Bower and Wilcox (1965).
- **Organic Matter:** A dried ground soil sample (1.0 g) was mixed with potassium dichromate reagent and sulfuric acid, followed by titration to a sharp green endpoint. A reagent blank was prepared for comparison.
- **Nitrate-Nitrogen:** A soil extract solution was treated with various reagents, and the samples were read at a wavelength of 540 nm on a spectrophotometer.
- **P and K Content of Soil:** Air-dried soil was mixed with carbon black and an extracting solution, shaken, and filtered for analysis.

Plant Nutrient Analysis;

Plant leaves were analyzed for nutrient uptake using the wet acid digestion method with a nitric acid-perchloric acid mixture (HClO3-HClO4), following the protocol adapted by a previous study.

Wet Acid Digestion:

The nitric-perchloric acid mixture was added to dried plant material and allowed to stand overnight. The mixture was then digested at 150°C and 235°C until all traces of nitric acid disappeared. After cooling, the volume was made up with distilled water, and the P and K contents were determined using a spectrophotometer.

Statistical Analysis:

A two-factor factorial design with RCBD was followed, and analysis of variance was performed on the data at each stage. Critical differences (C.D.) values were calculated at the 5% probability level.

Results and Discussion

Plant Height: Growth during the crop cycle, expressed as plant height, spread, and stem diameter, is shown in Tables 1 and 2. Among the six different vegetables, Chinese cabbage attained the maximum plant height, followed by broccoli and cabbage. The minimum plant height was recorded in kohlrabi and lettuce. The extent to which growth is limited by intercropping may vary with the genetic makeup of the different crops. The maximum increase in plant height was noted in Chinese cabbage, green lettuce, and cabbage (Table 1).

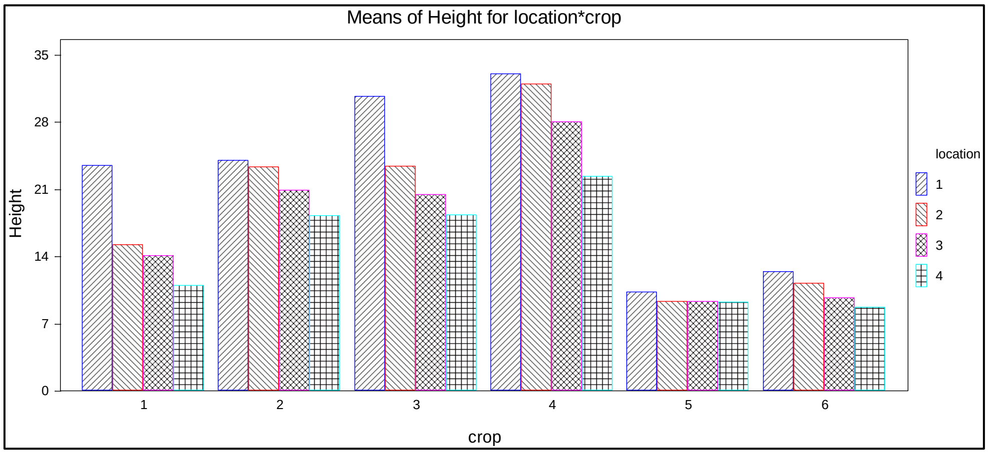

Figure 2: Effect of intercropping on plant height of six vegetables grown in three olive orchards (Mean Heights)

Locations 1: Open field condition, **2:** 10 years old orchard **3:** 25 years old orchard and **4:** 30 years old orchard

Crops 1: Cabbage, **2:** Chinese cabbage, **3:** Kohlrabi, **4:** lettuce, **5:** Lettuce leafy (Leafy red), **6:** Broccoli

The results concerning the age of olive trees revealed that the optimal plant height was achieved under open field conditions (control), with progressively lower heights observed in 10, 25, and 30-year-old orchards, respectively. A clear trend of decreasing plant height was associated with increasing shade intensity. The most significant increase in plant height occurred under open field conditions, followed by the 10-year-old orchard (Table 2).

Table 5: Effect of intercropping on growth of six vegetables grown in three olive orchards

Crop	Plant height (cm)	Increase in Plant height (cm)	Plant Spread (cm)	Increase in plant Spread (cm)	Stem diameter (cm)
Lettuce green Wave	15.95 C	10:00 A	19.86 CD	7.75 B	12.5 A
Cabbage	21.62 B	9.91 A	27.72 A	12.5 A	6.68 BCD
Broccoli	23.22 B	5.5 B	23.69 B	4.00 C	8.74 BC
Chinese Cabbage	28.83 A	11 A	22.13 BC	8.25 B	5.16 D
Kohlrabi	9.56 D	5.75 B	17.13 D	8.25 B	6.1 CD
Lettuce leafy red	10.51 D	4.2 C	19.5 CD	7.37 B	9.79 AB

Figures followed by different letters are significantly different at (p>o.o5), according to Duncan's multiple range test

Plant Spread:

Among the six vegetables, cabbage and Chinese cabbage showed the widest plant spread, followed by broccoli. The smallest spread was observed in kohlrabi and lettuce. Cabbage exhibited the most significant increase in plant spread, while broccoli had the least (Table 1). Regarding the olive trees, the largest plant spread was observed under open field conditions (control), followed by the 10, 25, and 30-year-old orchards, respectively. As shade intensity increased, plant spread decreased. The most substantial increase in plant spread occurred under open field conditions, followed by the 10-year-old and 25-year-old orchards (Table 2).

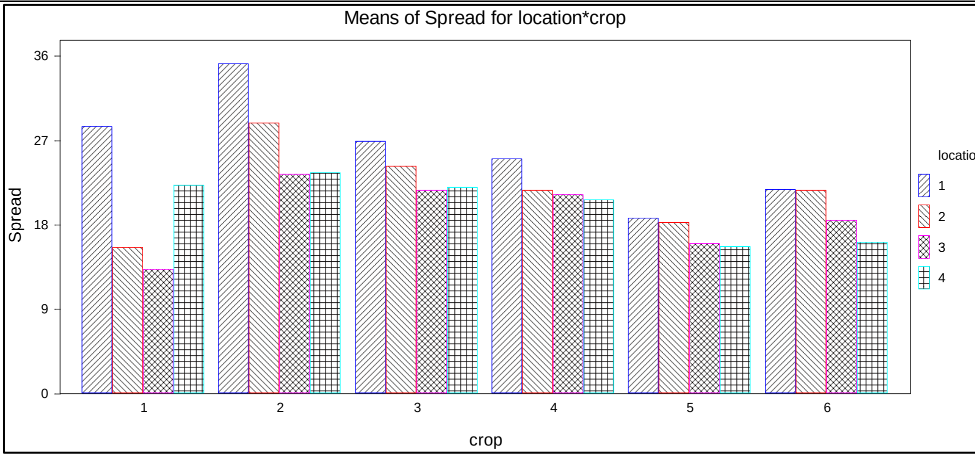

Figure 3: Effect of age on the growth of six vegetables grown in three olive orchards

Locations 1: Open field condition**, 2**: 10 years old orchard **3:** 25 years old orchard and **4:** 30 years old orchard

Crops 1: Cabbage **2:** Chinese cabbage**, 3:** Kohlrabi**, 4**: lettuce**, 5:** Lettuce leafy (Leafy red)**, 6:** Broccoli

Table 6: Effect of age of orchard on growth of six vegetables grown in three olive orchards

Location	Plant height (cm)	Increase in plant height (cm)	Plant Spread (cm)	Increase in plant Spread (cm)	Stem diameter (cm)
Open Field	22.3 A	8.55 A	25.9 A	9.61 A	11.7 A
10 Years	19.0 B	8.66 A	21.6 B	8.33 B	7.3 B
25 Years	17.0 C	7.33 B	20.0 B	7.80 B	7.0 B
30 Years	14.6 D	6.36 B	18.9 B	6.33 C	6.5 B

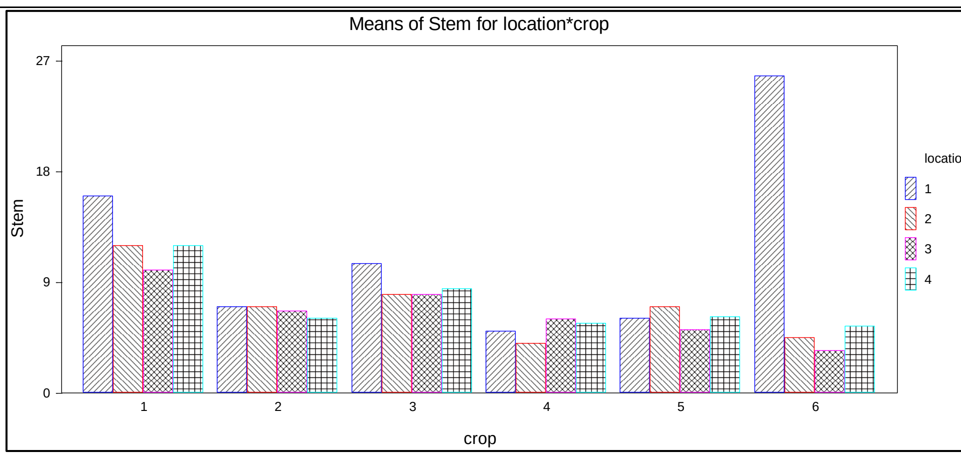

Figure 4: Effect of stem diameter on the growth of six vegetables grown in three olive orchards

Stem Diameter:

The greatest stem diameter was observed in green lettuce and red lettuce, with Chinese cabbage showing the smallest diameter (Table 1). In terms of olive tree age, the largest stem diameter was recorded under open field conditions (control), followed by the 10, 25, and 30-year-old orchards, respectively. A reduction in stem diameter was noted with increasing shade intensity (Table 2).

Locations 1: Open field condition, **2:** 10 years old orchard **3:** 25 years old orchard and **4:** 30 years old orchard

Crops 1: Cabbage, **2:** Chinese cabbage, **3:** Kohlrabi, **4:** lettuce, **5:** Lettuce leafy (Leafy red), **6:** Broccoli

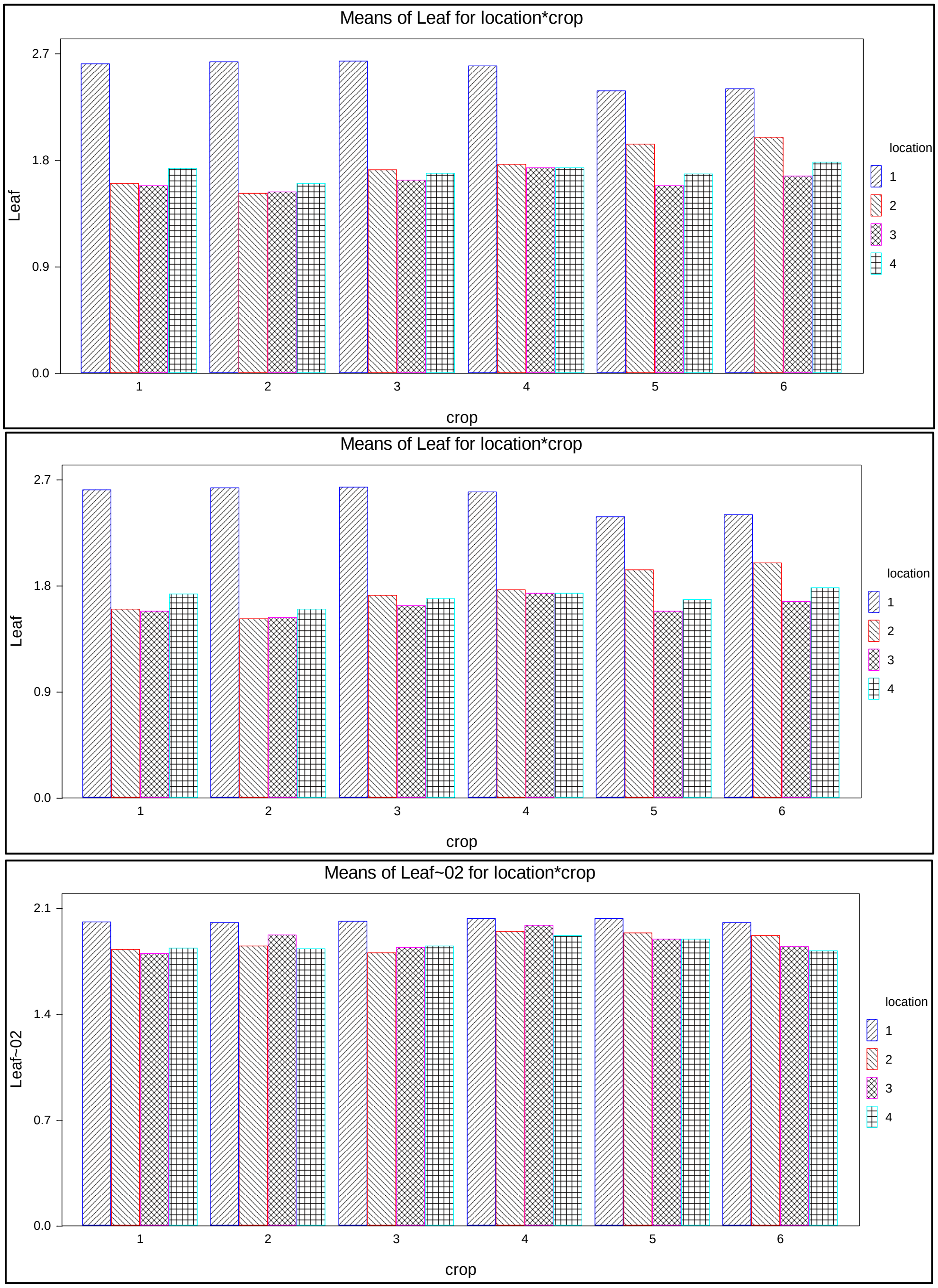

Figure 5 (a), (b) and (c): Effect of Leaf -02 Nitrogen on the growth of six vegetables grown in three olive orchards

Plants grown under optimal light conditions demonstrated more vigorous growth, characterized by greater plant height, spread, and stem diameter. This enhanced growth is likely attributed to increased photosynthetic efficiency under adequate sunlight, which stimulates cellular processes and promotes overall plant development. Based on these findings, we recommend adjusting the spacing of crops planted alongside olive trees to reduce interspecific competition, especially in terms of light availability for crops grown during the olive dormancy period.

Leaf Nitrogen:

Recent studies on the effect of intercropping with six selected vegetables revealed no significant difference in leaf nitrogen levels (Table 3).

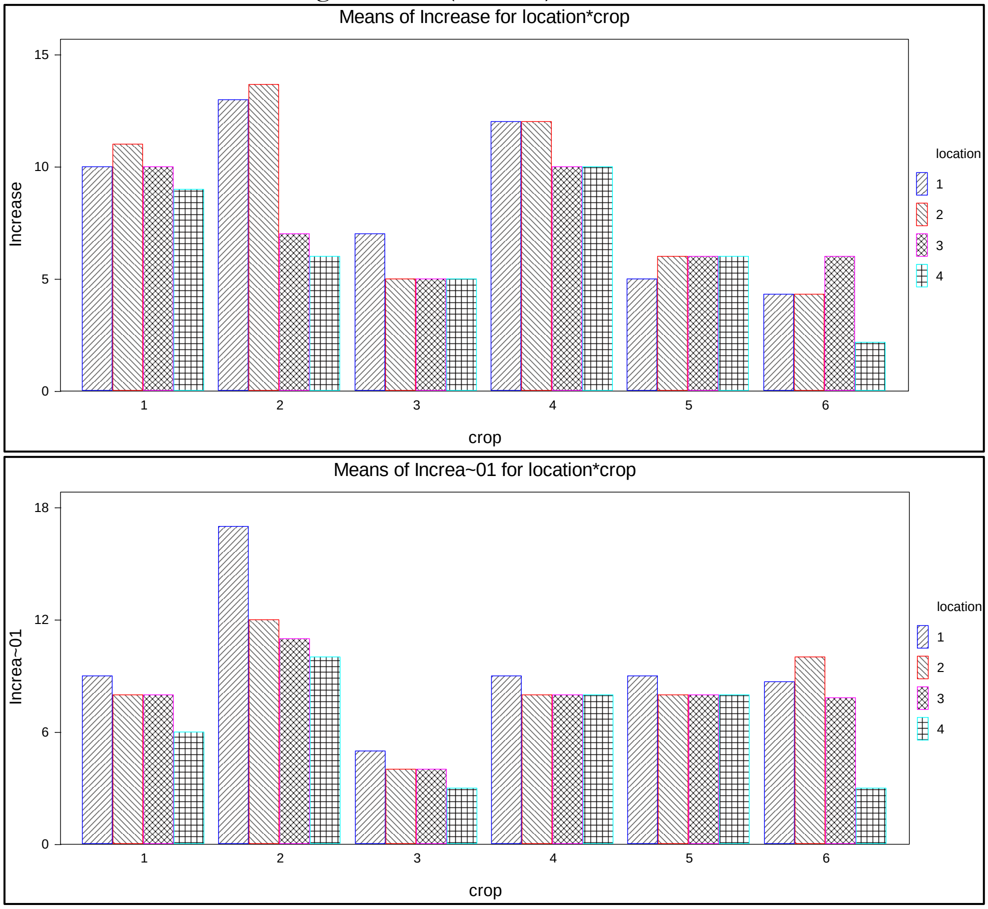

Figure 6 (a) and (b): Effect of Leaf -02 Nitrogen on the growth of six vegetables grown in three olive orchards

For the experiment, four olive orchard sites were selected to assess nutrient uptake in the leaves of both olive trees and intercropped vegetables. The highest leaf nitrogen uptake was observed in the open field (control), followed by the 10-year, 30-year, and 25-year-old orchards, respectively (Table 4).

Leaf Phosphorus:

The effect of intercropping on phosphorus uptake among six selected vegetables from different sites was analyzed. The highest phosphorus uptake was recorded in red lettuce and green lettuce, followed closely by broccoli, kohlrabi, and Chinese cabbage. Cabbage showed the lowest phosphorus uptake (Table 3). Among the four olive orchards, the highest phosphorus uptake was again observed in the open field (control), followed by the 10-year, 30-year, and 25-year-old orchards, respectively (Table 4).

Leaf Potassium:

Data analysis revealed significant differences in leaf potassium uptake among the six vegetables. Chinese cabbage and kohlrabi exhibited the highest potassium uptake, followed closely by cabbage and red lettuce. Broccoli and green lettuce had the lowest potassium uptake (Table 3). In the context of the olive orchards, potassium uptake was highest in the open field (control), followed by the 10-year, 25-year, and 30-year-old orchards (Table 4).

Table 7: Effect of intercropping on dry matter accumulation and NPK uptake of six vegetables grown in three olive orchards

Crop	Leaf N	Leaf P	Leaf K	Dry matter

Lettuce green Wave	1.88 A	0.23 AB	1.86 C	244.75 B
Cabbage	1.82 A	0.2 C	1.9 BC	415 A
Broccoli	1.91 A	0.22 BC	1.87 C	394.17 A
Chinese Cabbage	1.95 A	0.21 BC	1.97 A	472.33 A
Kohlrabi	1.89 A	0.22 BC	1.93 AB	193 B
Lettuce leafy red	1.96 A	0.25 A	1.89 BC	247.25 B

Table 8: Effect of age of olive orchard on dry matter accumulation and NPK uptake of six vegetables grown in three olive orchards

Location	Leaf N	Leaf P	Leaf K	Dry matter
Open Field	2.54 A	0.25 A	2.01 A	21 A
10 Years	1.75 B	0.20 B	1.88 B	17 B
25 Years	1.62 B	0.21B	1.88 B	10 C
30 Years	1.70 B	0.22B	1.85 B	8.0 C

Dry Matter Content:

The results showed that, among the six vegetables, Chinese cabbage had the highest dry matter accumulation, followed by cabbage, broccoli, and then red and green lettuce. The lowest dry matter content was observed in kohlrabi (Table 3). In the selected olive orchards, significant differences in dry matter content were noted. The highest dry matter content was recorded in the open field (control), followed by the 10-year-old and 25-year-old olive orchards. The 30-year-old olive orchard had the lowest dry matter content (Table 4).

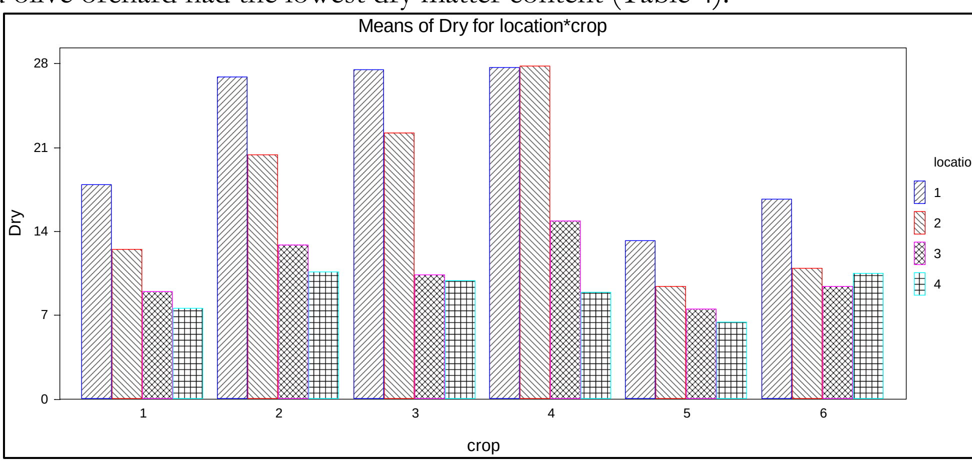

Figure 7: Effect of Dry Matter content on the growth of six vegetables grown in three olive orchards

Leaf Relative Water Content:

In the experiment, Chinese cabbage and cabbage exhibited the highest leaf relative water content (LRWC) among the six selected vegetables, followed by broccoli, green lettuce, and red lettuce. The lowest LRWC was observed in kohlrabi (Table 5). Regarding the age of the olive orchards, the 30-year-old orchard had the highest LRWC, followed by the 25-year-old orchard. The open field (control) and the 10-year-old orchard showed similar LRWC values (Table 6).

Table 9: Effect of intercropping on Leaf relative water contents (LRWC), Chlorophyll and yield of six vegetables grown in three olive orchards.

Crop	LRWC	Chlorophyll	Yield per plant	Yield t/ha
Lettuce green Wave	6.04 B	2.19 A	11.73 B	31.82 BC
Cabbage	10.25 A	1.3 BC	17.67 A	35.97 AB
Broccoli	9.73 A	0.97 C	17.47 A	30.68 C
Chinese Cabbage	11.66 A	0.54 D	19.78 A	30.11 C
Kohlrabi	4.76 B	0.47 D	9.15 B	40.17 A

Lettuce leafy (Leafy red)	6.1 B	1.48 B	11.86 B	30.49 C

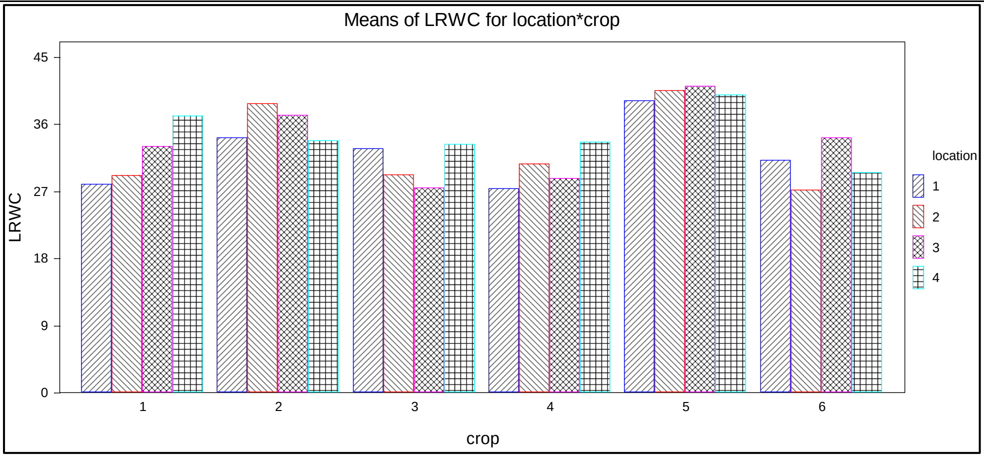

Figure 8: Effect of Leaf relative water content on the growth of six vegetables grown in three olive orchards

Plant Chlorophyll:

The test demonstrated the effect of intercropping on six selected vegetables. The highest level of chlorophyll was found in green lettuce, followed by red lettuce and cabbage. Broccoli showed a slightly lower chlorophyll level. The lowest chlorophyll levels were observed in Chinese cabbage and kohlrabi (Table 5).

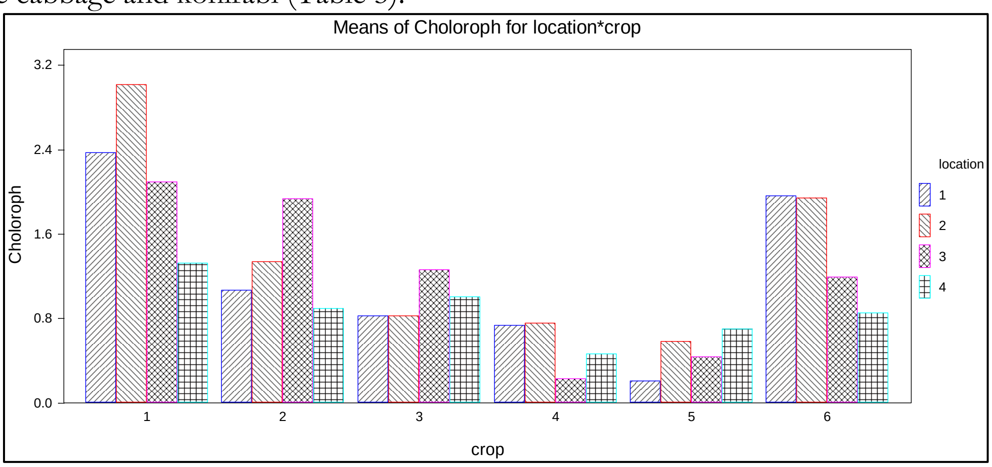

Figure 9: Effect on Plant Chlorophyll on the growth of six vegetables grown in three olive orchards

The experiment showed that among the four sites, the highest chlorophyll levels were recorded in the control (open field), followed by the 10-year-old and 25-year-old olive orchards. The lowest chlorophyll levels were observed in the 30-year-old olive orchard (Table 6). Chlorophyll, essential for photosynthesis, directly affects the plant's ability to produce food. Lower chlorophyll levels, often due to reduced light availability, can impair photosynthetic efficiency and stomatal conductance, leading to a decrease in the overall food production rate of the crops.

Table 10: Effect of age of olive orchard on Leaf relative water contents (LRWC), Chlorophyll and yield of six vegetables grown in three olive orchards

Location	LRWC	Chlorophyll	Yield per plant	Yield t/ha
Open Field	32	1.4 A	526 A	13 A
10n Years	32	1.1A	371 B	9 B
25 Years	33	1.1 A	223 C	5 C
30 Years	34	0.8 B	189 C	4 C

Yield Per Plant:

The experiment demonstrated that Chinese cabbage yielded the highest production per plant, followed by cabbage and broccoli. Green lettuce and red lettuce had slightly lower yields, while kohlrabi produced the least yield per plant (Table 5). Among the selected orchard sites, the highest yield per plant was recorded in the open field (control), with the 10-year-old olive orchard showing the next highest yield. The 25-year-old olive orchard yielded slightly less, and the lowest yield was observed in the 30-year-old olive orchard (Table 6).

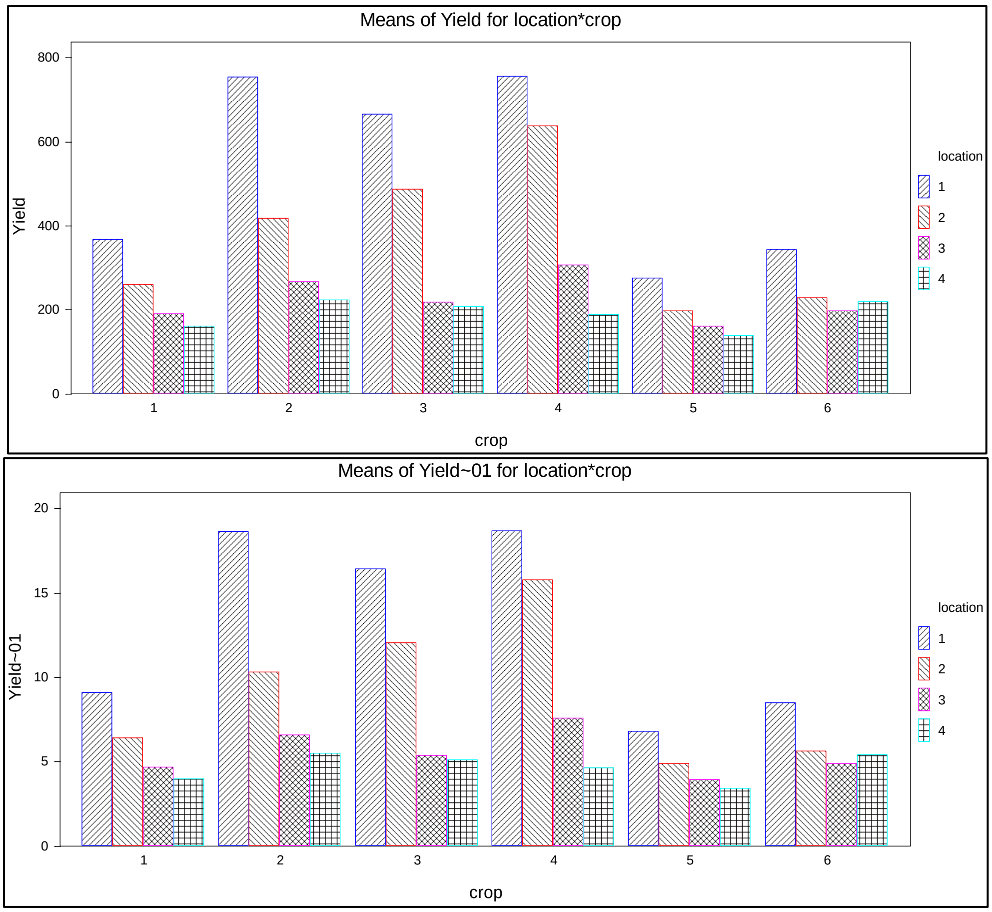

Figure 10 (a) and (b): Effect of Yield on the growth of six vegetables grown in three olive orchards

Yield per/ha:

The experiment demonstrated that among the six selected vegetables, kohlrabi and cabbage yielded the highest, followed by green lettuce. Broccoli and red lettuce had similar yields, while Chinese cabbage produced the lowest yield (Table 5). When assessing the effect of olive orchard age on vegetable yields, the control (open field) produced the highest yield, with the 10-year-old olive orchard showing slightly lower yields. The 25-year-old orchard yielded somewhat less, and the 30-year-old orchard had the lowest yield (Table 6). These results indicate that increased shading from olive trees, as well as the age of the orchard, negatively impacts vegetable yield. This aligns with previous research [18], which shows that shading generally reduces yield. Our findings suggest that the extent of shading inversely affects yield, with maximum shading resulting in reduced yields, while partial shading can enhance vegetable production [11][19].

Discussion

Variations in light availability have a significant impact on plant growth, including morphogenesis, nutrient uptake, storage, quality, and photosynthetic efficiency [20]. Previous studies have highlighted the detrimental effects of shading on crop production, with the extent of impact depending on light duration and intensity [21]. This study supports these findings, showing that intercropping under olive trees adversely affects the biomass and yield of selected vegetables. Light is critical for plant development, and its availability in intercropping systems plays a crucial role [22]. Research by [7] and [23] indicated that maize growth declined under jujube tree shade due to inadequate sunlight. Similarly, [24] reported reductions of 29% and 38% in soybean and maize production, respectively, in tree-based agroforestry systems in China. [25] observed a 56% reduction in chickpea and faba bean yields under olive trees, and [26] found decreases in wheat and barley yields under tree canopies.

[27] confirmed that consistent shade from trees significantly diminishes crop production. In this study, intercropping with olive trees clearly impacted vegetable growth and yield, with results varying by species and characteristics. Only cabbage and kohlrabi performed better under shaded conditions. The reduction in plant height, likely due to decreased photosynthesis, aligns with Ullah et al. (2012), who reported similar effects in anise under artificial shading. Further research is needed to fully understand the complex relationship between shading and yield in intercropping systems.

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