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*Original Article*

# Yield, Quality, Land Equivalent Ratio, and Economic Viability of Intercropping Combinations of Summer Squash, Faba Bean and Strawberry

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## Abstract:

Intercropping system has been reported to enhance quality and yield obtained per unit area. Therefore, the current study was carried out to assess the impact of intercropping of Zucchini or broad beans with strawberry and also, intercropping (IC) Zucchini with broad beans on growth, quality, yield and the economic viability of the studied crops in the mixed IC, compared to the mono-cropping of these crops. A field experiment was carried out during 2017- 2018 and 2018-2019. According to results of this study, intercropping of strawberry with broad beans achieved significantly the highest levels of anthocyanin content in strawberry fruits compared to the other treatments in both seasons. Maximum yield of strawberry crop was obtained from sole cropping as well as that obtained from strawberry-broad beans intercropping. Intercropping of Zucchini with broad beans resulted in significantly higher yields of both crops as compared with their sole cropping. Yield of broad bean and Zucchini increased by 18.1% and 26.9% respectively as compared with their sole cropping which indicate yielding efficiency enhancement as a result of intercropping. Land equivalent ratio (LER) of strawberry- Zucchini intercropping was, on average 1.2 for both years. Whereas, with regard to strawberry-broad beans intercropping was, on average for 1.3 for both years, while it was 2.45 when Intercropping Zucchini with broad bean. Intercropping Zucchini with broad bean gave the highest relative yield for both of them compared with the other treatments and also, the highest monetary advantage index (MAI).

***Keywords:*** *Main crop; Secondary crop; Yield components; Intercropping system*

## Introduction

Because of the rapidly growing human population, it is becoming necessary to enhance crop productivity or to increase the use efficiency of existing croplands (Wiebe *et al.*, 2021). Lately, intercropping has received a great attraction because of the yield improvement particularly with the rising challenges of environment, resources, and food (Liu *et al.,* 2017). Intercropping systems are thought to be helpful for solving these challenges and are already practiced in many parts of the world (Francis, 1985). Intercropping is one of the

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conventional practices which is the cultivation of two or more crops together within the same area (Kizilsimsek and Erol, 2000), and within a given year (Willey *et al*., 1989). Intercropping systems increase crop and land productivity due to its positive effects on the soil quality (Li *et al*., 1999) and on the efficiency of resources (Li *et al*., 1999) including water (Morris and Garrity, 1993), light, and available plant nutrients (Mucheru-Muna *et al.,* 2010). Additionally, intercropping offers conservation for soil as a result of the increasing ground cover (Jarenyama *et al.,* 2000). It also minimizes pesticides use by controlling pests and diseases which is essential for better human health (Pelzer *et al.,* 2012). It suppresses weeds and decreases the chance of total crop failure as the improved yield of one crop compensates for the yield reduction of the other (Baumann *et al.*, 2000). The improved quantity and quality of crop yield through intercropping system minimize the total cost of production, and consequently increase the profitability (Guvenc and Yildirim, 2005 and 2006).

Strawberries (*Fragaria* × *ananassa*) are recommended for human consumption for their health benefits (Nile and Park, 2014), antioxidant properties, and high nutritional values (Tulipani *et al*., 2014). Strawberries are cultivated for local use and exportation, and are consumed as fresh or processed like jam and juice. Recent studies showed an increase in the land equivalent ratio and gross income in the garlic with strawberry intercropping systems (Hata *et al*., 2019). Still, more information on the use of appropriate intercropping systems in strawberry production is needed.

Generally, intercropping with legumes enhances soil fertility (Yuvaraj *et al*., 2020) and nutrient utilization which enhance crop productivity per unit area of the land due to the atmospheric nitrogen fixation by legumes root nodules. Faba beans are commonly utilized in intercropping systems (Lithourgidis *et al*., 2011). Intercropping with faba bean enhances land and N use efficiency (Shanmugam *et al*., 2021) because they improve nitrogen content in soil, consequently, enhance yields and increase economic returns (Lithourgidis *et al*., 2011). Legumes, including Faba beans benefit all other plants especially heavy feeders like zucchini as nitrogen-fixing plants providing them with the nutrients they need. The large leaves of zucchini plants might shade the soil and reduce the germination of weeds, while the spiny leaves prevent rodents that might enjoy a bean or strawberry fruits (Gliessman, 1988). Therefore, the aim of the present study was to evaluate the efficiency of strawberry, zucchini and faba beans grown as sole crops and when intercropped with each other on yield, quality and economic return.

## Materials and Methods

### 1. Experimental design and treatments

A field experiments was carried out at the Experimental Farm of the Vegetable Crops Department, Faculty of Agriculture, Assiut University, Assiut, Egypt, during 2017-2018 and 2018-2019 winter seasons. Soil texture of the experimental site was clay with an average pH of 7.65. Planting was carried out in the last week of September for strawberry and zucchini, whereas it was in the first week of October for faba bean in both years. Strawberry (*Fragaria x ananassa* L. Duch.) namely, “Hybrid 43”as main crop was intercropped with faba bean (*Vicia faba* L.) cultivar namely, “Giza 3” and zucchini (*Cucurbita pepo* L.) hybrid namely, “New Eskandrany F1”as secondary crops in the two successive seasons. The experiment consisted of eighteen plots in total (six treatments and three replications) in first season of the study. Treatments were as follows: strawberry-faba bean intercropping system, strawberry- zucchini intercropping system, sole faba bean (planted on both sides of row), sole zucchini (planted on the southern side of the row), and sole strawberry (planted at both sides of the row). Second season of experiment consisted of the same treatments but faba bean-zucchini intercropping treatment was added to the experiment. Therefore, the experimental plots were 21 in total in the second season (consisted of seven treatments and three replications).

Cold-stored (frigo) transplants of strawberry were obtained from the Faculty of Agriculture, Ain Shams University, Cairo, Egypt (Eagseed company). Before transplanting, plantlets were dipped in a fungicide 0.2% Rizolex solution for 20 minutes. Strawberry planting was done 30 cm apart on both sides of rows in both years. Healthy faba bean seeds were sown 30 cm apart on the northern side of the rows, whereas healthy zucchini seeds were sown 40 cm apart on the southern side of the row. Each experimental plot consisted of two rows. Each row was 3.5 meters long and with 70 cm width. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Agricultural practices of irrigation, pest control, disease control, etc., were applied as recommended for strawberry production.

## 2. Data collection

### 2.1. Data collection for strawberry crop

#### 2.1.1. Yield and its components

Fruits were harvested from the last week of February to the end of April. Number of fruits /plant was calculated at each fruit harvest. Average fruit weight (g), fruit length (cm) and fruit diameter(cm) were measured from two midterm pickings from each plot. Fruit length was measured from the calyx plug to the apex of the fruit using a Vernier clipper. Fruit diameter (cm) was also measured with the use of Vernier clipper. Early fruit yield of the first 3 pickings were weighed from each plot then expressed in Kg per feddan. All over the growing season, harvested fruits were weighed and total yield (kg/feddan) was calculated.

#### 2.1.2. Fruit quality measurements

Quality parameters were measured at the two midterm pickings. Total soluble solids percentage (TSS%) was determined using a hand refractometer. Total acidity was estimated according to (AOAC, 1984). TSS/ acid ratio was calculated. Total anthocyanin content (mg/100 g of fruit fresh weight) was determined according to Rabino and Mancinelli (1986). Vitamin C content (mg/100 g of fruit fresh weight) was estimated by the titration method according to AOAC (2000).

### 2.2. Data collection for faba bean crop

#### 2.2.1. Vegetative growth measurements

Vegetative parameters for five plants of faba bean in each plot were recorded: plant height (cm), number of branches per plant were counted, and stem diameter (cm) was measured using a Vernier clipper.

#### 2.2.2. Yield and its components

Pod length (cm) and pod diameter (cm) were measured with the use of a Vernier clipper. Number of seeds per pod was counted and seeds from each plot were weighed, then total yield (ton/feddan) was calculated.

### 2.3. Data collection for zucchini crop

#### 2.3.1. Yield and its components

Fruits were harvested from the last week of December until the end of April. Three midterm pickings from each plot were used to estimate fruit length (cm), fruit diameter (cm) (at the top, middle, and bottom positions of each fruit), and average fruit weight (g). Fruit length and diameter were measured with the use of a Vernier clipper. Early yield was estimated for the first 3 pickings in kg/feddan, then expressed as (ton/ feddan). All over the growing season, harvested fruits were weighed, and total weight was calculated in kg/feddan, then expressed as total yield (ton/ feddan).

### 2.4. Intercropping efficiency parameters

#### 2.4.1. Land equivalent ratio (LER)

Land equivalent ratio (LER) was calculated according to Willey, (1979a) as follows:

LER = (intercropping yield of main crop/ monocrop yield of main crop) + (intercropping yield of second crop/ monocrop of a second crop).

When the LER value is one, there is no advantage to intercropping over sole cropping while for values of LER < 1, means that intercropping is less effective as comparing to sole crop, that means more land is needed to produce a given yield by each component as an intercrop. However, LER > 1, means that intercropping is advantageous and more effective regardless productivity compared to sole cropping (Vandermeer, 1989).

#### 2.4.2. Aggressiveness values

Aggressiveness values were calculated according to McGilchrist (1965) where:

$$\text{Aggressiveness for main crop} = \frac{\text{intercropping yield of main crop}}{\text{expected yield of main crop}} - \frac{\text{intercropping yield of second crop}}{\text{expected yield of second crop}}$$

$$\text{Aggressiveness for second crop} = \frac{\text{intercropping yield of second crop}}{\text{expected yield of second crop}} - \frac{\text{intercropping yield of main crop}}{\text{expected yield of main crop}}$$

$$\text{The expected yield} = \text{yield of monocrop} \times \text{ the fraction of the area occupied by intercropping (0.5 for the 3 crops)}$$

### 2.4.3. Monetary advantage index (MAI)

Economic feasibility of the study should be in terms of the value of land saved, biased on the land return. MAI was calculated according to Willey (1979a):

$$\text{MAI} = \frac{\text{Value of combined intercrops} \times \ (\text{LER} - 1)}{\text{LER}}$$

In Egyptian pound, strawberry price was 15 L.E./kg fruits, 28 L.E./kg for faba bean seed yield, and 8 L.E./kg for zucchini fruits as an average market price over the two seasons of the study.

## 3. Statistical analysis

Data were statistically analyzed using 1998-2004 CoHort Software, CoStat Software, version 6.303 (798 Lighthouse Ave. PMB 320, Monterey, CA, 93940, USA). Means of the treatments were compared by Least Significant Differences (LSD) at 5% probability level.

**Table 1. Effect of intercropping treatments on fruit number/plant, berry weight (g), fruit diameter (cm), fruit length (cm), early yield (kg/fed) of first 3 pickings and total yield (kg/fed) of strawberry plants (main crop) cv. "hybrid 43" in the growing seasons of 2017/2018 and 2018/2019, respectively.**

| Treatment | Fruits number /plant | Average berry weight (g) | Fruit diameter (cm) | Fruit length (cm) | Early yield (kg/fed) | Total yield (kg/fed) |
|---|---|---|---|---|---|---|
| **Season 1** | | | | | | |
| **Strawberry North** | 8.27 a | 8.63 ab | 3.11 a | 3.56 a | 484.50 a | 1362.89 a |
| **Strawberry South** | 10.29 a | 8.28 ab | 2.97 a | 3.33 a | 356.90 a | 1656.57 a |
| **Strawberry - Zucchini** | 4.78 b | 9.78 a | 3.41 a | 3.80 a | 333.33 ab | 905.82 b |
| **Strawberry - Beans** | 8.55 a | 7.32 b | 2.98 a | 3.31 a | 90.48 b | 1255.66 ab |
| **Season 2** | | | | | | |
| **Strawberry North** | 8.15 a | 9.44 a | 3.07 b | 3.84 b | 597.89 a | 1463.55 a |
| **Strawberry South** | 9.53 a | 9.64 a | 3.09 a | 3.73 b | 793.65 a | 1724.29 a |
| **Strawberry - Zucchini** | 3.17 b | 8.56 ab | 3.90 b | 4.90 a | 0.00 b | 568.25 b |
| **Strawberry - Beans** | 2.71 b | 7.64 b | 3.04 b | 3.93 b | 126.19 b | 395.24 b |

Differences between mean values followed by the same letter in each column are not significant using the Least Significant Difference test at $P \leq 0.05$.

## Results

### Effect of intercropping systems on strawberry yield and yield components

Sole planting of strawberry, particularly those grown on the southern side of the row gave the highest number of fruits/plant in both seasons of the study (Table 1). Lowest significant number of fruits/plant were found in strawberry zucchini system in the first season, and in the strawberry intercropped with either zucchini or faba beans systems in the second season of the study (Table 1). Strawberry-bean treatment had significantly the lowest average berry weight. No significant differences were found among other treatments as regard to the berry weight of strawberry. Also, no significant differences were found in fruit diameter or fruit length parameters among the different treatments in the first season (Table 1). However, strawberry-zucchini treatment gave the largest fruit diameter and length in both seasons. The highest significant early yield of the first three pickings and the total yield per feddan were obtained when planting strawberry as sole crop either in northern or southern side of row. However, those sole strawberry plants grown on the southern side of the row had the highest yields in both seasons (Table 1).

### Effect of intercropping systems on fruit quality of strawberry

Results obtained in the current study obviously indicated that intercropping system had significant effects on the anthocyanin content of strawberry fruits ($p \leq 0.05$) in both seasons (Table 2). Anthocyanin content of strawberry fruits increased when strawberry was intercropped with faba bean as comparedto the sole cropping. Regarding vitamin C content, fruits of strawberry planted as sole treatments or intercropped with Zucchini had significantly higher vitamin C content than those resulted from strawberry-faba bean treatment in the first season, whereas in the second season, fruits of sole strawberry treatments had significantly higher vitamin C content than those obtained from the strawberry-faba bean treatment (Table 2).

**Table 2. Effect of intercropping treatments on TSS, acidity, TSS/acidity, vitamin C (mg/100 g of fruit fresh weight), anthocyanins (mg/100 g of fruit fresh weight) of strawberry plants (main crop) cv. "hybrid 43" in the growing seasons of 2017/2018 and 2018/2019, respectively.**

| Treatment | TSS | Acidity | TSS/ Acidity | Vitamin C | Anthocyanins |
|---|---|---|---|---|---|
| **Season 1** | | | | | |
| **Strawberry North** | 8.25 a | 0.33 b | 24.59 a | 78.75 a | 22.06 c |
| **Strawberry South** | 8.13 a | 0.37 a | 21.89 b | 90.00 ab | 25.43 bc |
| **Strawberry -Zucchini** | 8.00 a | 0.33 b | 24.35 a | 69.00 ab | 28.79 b |
| **Strawberry -Beans** | 8.00 a | 0.33 b | 24.51 a | 57.00 b | 33.08 a |
| **Season 2** | | | | | |
| **Strawberry North** | 11.03 a | 0.38 a | 29.30 a | 66.00 a | 37.78 ab |
| **Strawberry South** | 11.33 a | 0.39 a | 29.22 a | 57.00 ab | 37.39 b |
| **Strawberry -Zucchini** | 10.40 a | 0.40 a | 26.24 a | 51.00 bc | 38.53 ab |
| **Strawberry -Beans** | 10.67 a | 0.39 a | 26.84 a | 39.00 c | 42.74 a |

Differences among mean values followed by the same letter in each column are not significant using the Least Significant Difference test at $P \leq 0.05$.

In the present study, the chemical characteristics such as a total soluble solids, acidity and TSS/acidity ratio of strawberry fruits were not significantly affected by intercropping treatments (Table 2) neither with faba bean nor with Zucchini in the second season of study,whereas, acidity level of fruits that were obtained from plants grown at the southern side of the row as sole stawberries treatment recorded significantly the highest acidity level in the first season (Table 2). Fruits from sole stawberries treatment grown at southern side of the row had significantly the lowest TSS/acidity ratio in the first season (Table 2).

**Effect of intercropping on vegetative growth and yield of faba beans**

Intercropping systems had significant effects on the vegetative growth of faba beans plants. Bean-strawberry treatments were taller and had significantly greater number of branches per plant and stem diameter as compared to the sole cropping in the first season (Table 3). In the second season of the study, also plant height and stem diameter of faba bean-strawberry treatment were significantly greater than those of the sole faba bean cropping. However, faba bean-zucchini treatment gave significantly larger increase in number of branches and stem diameter compared to the other two treatments in the second season (Table 3).

There were no significant differences in the number of seeds per pod and total yield (ton/feddan) of faba bean between the sole treatment and intercropping with strawberry (Table 3). Pod length was significantly longer in faba bean plants of faba bean-strawberry treatment than those of the sole faba bean treatment in both seasons (Table 3). Intercropping faba beans with zucchini significantly increased pod length for faba beans plants. In the second season, the highest significant pod length, pod diameter, number of seeds/pod, and yield that was increased by 18% was found in plants of the faba bean-zucchini system (Table 3).

**Table 3. Effect of intercropping treatments on plant height (cm), branch number, stem diameter(cm), pod length (cm), pod diameter (cm), number of seeds/pod, and yield (ton/fed) of faba bean plants cv. Giza3 in the growing seasons of 2017/2018 and 2018/2019.**

| Treatment | Plant height (cm) | Branch number | Stem diameter (cm) | Pod length (cm) | Pod diameter (cm) | Number of seeds/pod | Yield (ton/ fed) |
|---|---|---|---|---|---|---|---|
| | | | **Season 1** | | | | |
| **Sole faba Bean** | 117.93 b | 6.53 b | 1.11 b | 8.27 b | 1.66 a | 3.60 a | 2.20 a |
| **Strawberry-Bean** | 126.67 a | 8.00 a | 1.23 a | 9.03 a | 1.83 a | 3.87 a | 2.19 a |
| | | | **Season 2** | | | | |
| **Sole faba Bean** | 114.70 b | 5.93 ab | 1.24 c | 7.67 c | 1.55 b | 3.60 b | 2.04 b |
| **Strawberry-Bean** | 125.13 a | 5.67 b | 1.39 b | 8.37 b | 1.72 a | 3.67 b | 2.15 b |
| **Zucchini-Beans** | 127.67 a | 6.47 a | 1.67 a | 8.87 a | 1.75 a | 4.00 a | 2.41 a |

Difference between mean values followed by the same letter in each column are not significant using the Least Significant Difference test at $P \leq 0.05$.

## Effect of intercropping on yield and its components of zucchini

No significant differences were observed in any of the studied parameter of zucchini (fruit diameter, fruit length, average fruit weight, early yield, and yield) between the two studied intercropping treatments in the first season (Table 4). Also, in the second season, no significant differences were found in fruit length, average fruit weight, early yield, and yield between plants of sole zucchini treatment and the zucchini-strawberry treatment (Table 4). However, in the second season, plants of the zucchini-strawberry and zucchini-beans treatments had significantly higher fruit diameter (in the different parts of the fruit) than those of the sole zucchini cropping treatment (Table 4). Yield of plants of the zucchini-bean treatment were significantly higher than those of the zucchini-strawberry treatment (Table 4). In general, intercropping faba beans with Zucchini increased the total yield by 26.9% as compared with sole crop.

**Table 4. Effect of intercropping treatments on fruit diameter in different parts of the fruit (top, bottom, and middle), fruit length (cm), average fruit weight (g), early yield (ton/fed) of first 3 pickings, and total yield (ton/fed) of zucchini plants hybrid cv "New Eskandrany F1"in the growing seasons of 2017/2018 and 2018/2019.**

| Treatment | Fruit Diameter Top | Fruit Diameter Middle | Fruit Diameter Bottom | Fruit Length | Average Fruit | Early yield | Total yield |
|---|---|---|---|---|---|---|---|
| | | | Season 1 | | | | |
| **Sole Zucchini** | 2.40 a | 2.84 a | 2.77 a | 13.20 a | 101.01 a | 2.83 a | 6.31 a |
| **Strawberry- Zucchini** | 2.39 a | 2.99 a | 2.70 a | 13.12 a | 100.75 a | 3.96 a | 6.62 a |
| | | | Season 2 | | | | |
| **Sole Zucchini** | 2.34 b | 2.73 b | 2.56 b | 14.00 a | 114.54 a | 4.68 a | 8.57 ab |
| **Strawberry-Zucchini** | 2.84 a | 3.07 a | 2.93 a | 15.02 a | 102.93 a | 3.77 a | 6.81 b |
| **Zucchini-Beans** | 2.67 a | 3.08 a | 2.85 a | 15.01 a | 119.92 a | 6.86 a | 10.88 a |

Differences between mean values followed by the same letter in each column are not significant using the Least Significant Difference test at $P \leq 0.05$.

## Intercropping efficiency parameters

### Land equivalent ratio (LER)

The productivity of intercropping systems was evaluated in term of the land equivalent ratio (LER). Results in Table (5) indicated that Land equivalent ratio (LER) was greater than one in all treatments in both years except for the strawberry-zucchini treatment in the second season (Table 5). The highest value of LER (2.45) was observed in the zucchini-bean treatment in the second season. Average LER for both years was 1.2 for strawberry-zucchini intercropping treatment and 1.3 for strawberry-bean intercropping treatment. In all intercropping treatments, secondary crops had higher relative yield than the main crops, except for the zucchini-bean treatment in the second season where zucchini surpassed those of faba bean plants (Table 5).

### Aggressiveness

Aggressiveness is a value, which shows how much the relative yield of one crop component is greater than that of another (McGilchrist 1965). Data showed that both faba bean and zucchini crops were dominant when intercropped with strawberry, whereas zucchini was dominant when it was intercropped with faba bean (Table 5).

## Monetary advantage index (MAI)

Economic feasibility from using intercropping systems was expressed by calculating monetary advantage index (MAI). All treatments gave positive values of MAI except for the strawberry-zucchini treatment which gave negative 1755.76 value because its LER value was lower than 1 (Table 5). Results presented in Table 5 showed that the highest MAI value of 91474.22 was obtained in the case of zucchini-bean intercropping system in the second season, followed by strawberry-bean intercropping treatment (Table 5). Values of these MAI were positive because their LER was greater than one.

**Table 5. Relative yield of main and secondary crops, Land equivalent ratio (LER), aggressiveness for main and secondary crops, and monetary advantage index (MAI) values for the different intercropping systems in the growing seasons of 2017-2018 and 2018-2019.**

| Main Crop | Secondary Crop | Relative Yield Main Crop | Relative Yield Secondary Crop | LER | Aggressiveness for Main Crop | Aggressiveness for Secondary Crop | MAI |
|---|---|---|---|---|---|---|---|
| | | | | **Season 1** | | | |
| **Strawberry** | **Zucchini** | 0.30 | 1.05 | 1.35 | -1.49 | 1.49 | 17396.32 |
| **Strawberry** | **Beans** | 0.41 | 1.00 | 1.41 | -1.16 | 1.16 | 23360.23 |
| | | | | **Season 2** | | | |
| **Strawberry** | **Zucchini** | 0.18 | 0.79 | 0.97 | -1.23 | 1.23 | -1755.76 |
| **Strawberry** | **Beans** | 0.13 | 1.05 | 1.18 | -1.86 | 1.86 | 9987.75 |
| **Zucchini** | **Beans** | 1.27 | 1.18 | 2.45 | 0.18 | -0.18 | 91474.22 |

## Discussion

Intercropping has been identified as a system that boost profit by maximizing land use as a result of gaining yield of a second crop (Thobatsi, 2009), conserving soil, and balancing plant nutrition (Shetty *et al.*, 1995). Intercropping results in higher yields as one component of crop is added to another. Therefore, total planting density is generally more than those for sole crops (Willey, 1979b), which results in efficient use of nutrients by intercrops than sole crops (Midmore, 1993). Indeed, increasing productivity per unit area and planting diversity of crops are considered the most important reasons for applying intercropping (Sullivan, 2003).

In our experiment, sole strawberry plants, particularly those grown on the southern side of the row had higher yields than the intercrops. This is in agreement with (Chen *et al.*, 2004), who found that strawberry yield was unaffected by the strawberry-snap beans intercropping system. The authors stated that this might occur due to nitrogen fixing ability of snap beans and extensive root system of strawberry (Chen *et al.,* 2004). Similar findings were observed by (Karlidag and Yildirim, 2007) where intercropping strawberry with faba beans didn't affect the yield of strawberry. This might be due to the difference in root distribution for both crops which lead to low competition between them (Ragab *et al*., 2014). Indeed, Wilson (1988), found that root competition had a greater effect on plant growth and resource fetching than shoot competition (Wilson, 1988). Also, Woolley and Davis (1991) reported that faba bean was a weaker competitor for growth resources than some other vegetables. Dane *et al.* (2019) found that intercropping strawberries with legumes gave the same yield as in the traditional system. On contrary, Willey (1979a) reported that intercropping gave higher and greater stability of yields compared with sole cropping.

In current study, strawberry yield of strawberry-zucchini treatment was lower than the sole strawberry treatments. Duval (2005) found that yield of sole strawberry was better than that of intercropped strawberry-zucchini, whereas strawberry yields were not reduced when summer squash was intercropped during the last week in February. Duval (2005) also found no significant differences in the yield of strawberry when intercropped with summer squash, pickling cucumber, musk melon, or bell pepper. Santos *et al*., (2008), showed that yield of strawberry was unaffected when intercropped with cucumber, summer squash, or musk melon when planted between 25 Jan. and 23 Mar (Santos *et al*., 2008).

With regard to intercropping strawberry with faba bean, a significant increase in plant height, number of branches/plant, stem diameter and pod length were observed but didn't affect faba bean yield. On the other hand, Karlidag and Yildirim (2007) observed a yield increase in intercropped strawberry-broad bean system as compared to sole cropping. Several studies have indicated that intercropping was more productive than single cropping because of the complementary effect of intercrops. Intercropping involving legumes has been found to be more efficient (Adeniyi, 2011). The intercropping with legumes may improve soil fertility to benefit a subsequent crop. No significant differences were observed in any of the studied parameter of zucchini (fruit diameter, fruit length, average fruit weight, early yield, and yield) between zucchini-strawberry and zucchini-beans treatments in the first season. However, in the second season, plants of the zucchini-strawberry treatment had significantly higher fruit diameter (in the different parts of the fruit) than those of the sole zucchini cropping treatment. This is in agreement with results of Karlidag and Yildirm, (2009) who found that yields of summer squash, lettuce, onion, and radish were not affected when intercropped with strawberry (Karlidag and Yildirm, 2009). In the second season of our study, plants of zucchini intercropped with faba beans had significantly higher yield than those of zucchini-strawberry treatment. Legumes are known for their advantage of fixing air nitrogen into the soil, and they can release fixed N to the non-legume crops (Ledgard and Giller, 1995; van Kessel and Hartley, 2000). Consequently, other plants benefit by providing the nutrients they need to grow (Ledgard and Giller, 1995).

The bioavailability of anthocyanin is considered as a key factor for maintaining better human health (Bridle and Timberlake, 1997). Highest anthocyanins values were obtained from the strawberry-beans intercropping treatment. This disagrees with results by Dane *et al*. (2019) who showed that quality of strawberries when intercropped with legumes is the same as in a traditional growing system. No significant differences were found in fruit content of vitamin C, acidity, and soluble solids content of strawberry fruits. Similarly, Karlidag and Yildirim, (2007) showed that the chemical characteristics such as ascorbic acid, total soluble solids, and titratable acidity of strawberry fruits were not significantly affected by intercropping with broad bean or with lettuce (Karlidag and Yildirim, 2007).

The land equivalent ratio (LER) refers to the amount of land needed to grow both crops together relative to that required to grow sole crop of each and give similar yield. LER measures the advantages of using intercropping systems on combined yield of both crops (Amanullah *et al*., 2016). In our study, LER was greater than one in all treatments in both years except for the strawberry-zucchini treatment in the second season. The highest value of LER (2.45) was observed in the zucchini-bean treatment in the second season. Values of LER greater than one indicate that land use is more productive and efficient in intercrops than sole cropping (Abera *et al*., 2005). Our results indicate that intercropping is more productive than sole cropping. In agreement with our results, in a study by Willey (1985), LER of zucchini-faba bean intercropping system were greater than 1.0 and were more efficient as regard to land utilization than sole crop. Also, Karlidag and Yildirim (2007) showed that intercropping strawberry with faba bean had higher productivity than when each crop was grown as a sole due to the complementary effects of both.

Aggressiveness is a competitive index which measures how much the relative yield of one crop component is greater than that of another (McGilchrist 1965). The present results revealed that all secondary crops were more dominant and stronger competitor than strawberry in all intercropping treatments that included strawberry crop. Also, in our study, zucchini plants had higher relative yields and competed more than bean plants in the zucchini-bean intercropping treatment. This indicates a bigger difference in the competitive abilities between the secondary crops and strawberry and also between zucchini and bean plants. Consequently, bigger differences between the actual and the expected yield with those intercropping systems (Willey, 1979a). Intercropping faba bean and squash as when grown in combination resulted in greater yields than if they were grown separately. Also, Hadidi *et al.* (2011) found that intercropping beans with summer squash gave the highest significant yield. All values of MAI were positive except for strawberry-zucchini treatment of the second season. The highest MAI value of 91474.22 was in zucchini-bean treatment, followed by strawberry- bean intercropping system. This could be explained as all LER values were greater than one except for the strawberry-zucchini treatment of the second season. In line with these results, Abou-Keriasha *et al.* (2012) stated that using intercropping systems can be gainful giving higher MAI values and economic feasibility.

## Conclusion

The foremost common goal of intercropping is to make effective use of farm inputs (like sunlight, nutrients and water) with minimum cost of cultivation and without affecting the fertility of land in addition to produce a higher yield from a given piece of land. Generally, intercropping systems result in effective use of land also, improved fruit quality. Maximum yield of strawberry crop was obtained from sole cropping as well as that obtained from strawberry-broad beans intercropping. Intercropping strawberry with broad beans increased anthocyanin content compared to the sole cropping.

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# المحصول والجودة ومعدل استغلال الارض والجدوى الاقتصادية لمحاصيل الفراولة والفول والكوسة المحملة

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**ملخص**

أجريت التجربة الحقلية لهذه الدراسة خلال موسمين متتاليين ٢٠١٧/٢٠١٨ و ٢٠١٨/٢٠١٩. وتمت زراعة ثلاث محاصيل وهى الفراولة والفول و الكوسة، واستخدم تصميم القطاعات الكاملة العشوائية مع ثلاث مكررات. وكان الهدف من الدراسة هو دراسة تأثير تحميل الفراولة مع كل من محصولي الفول والكوسة وكذلك دراسة تحميل الفول مع الكوسة (في الموسم الثاني فقط) على المحصول والجودة وكذلك الجدوى الاقتصادية مقارنة بزراعة تلك المحاصيل بمفردها.

اوضحت النتائج المتحصل عليها ان تحميل الفراولة مع الفول أدى الى زيادة محتوى الثمار من الانثوسيانين مقارنة بباقي المعاملات المستخدمة في موسمي الدراسة. لوحظ ان اعلى محصول للفراولة تم الحصول علية سواء عند تحميل الفراولة مع الفول او عند زراعة الفراولة بمفردها. ادى تحميل الكوسة مع الفول الى زيادة في المحصول بمقدار 18,1%، 26,9% لكل من محصولي الفول والكوسة على التوالي مقارنة بالمحصول الناتج من الزراعة المنفردة. ويتبين من هذه الدراسة ان التحميل يعتبر طريقة مؤثرة في زيادة الانتاجية. وكان متوسط الكفاءة التمثيلية لاستغلال الارض للموسمين1,2 وذلك عند تحميل الفراولة والكوسة معا، بينما كانت الكفاءة التمثيلية 1,3 عند تحميل الفراولة مع الفول كمتوسط لموسمي الدراسة. اما بالنسبة للكفاءة التمثيلية لاستغلال الارض في حالة تحميل الفول مع الكوسة فكانت القيمة 2,45 وذلك في الموسم الثاني وهى الأعلى مقارنة بباقي المعاملات المستخدمة وأيضا اعطت أعلى عائد اقتصادي.