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STRAWBERRY INTERCROPPING WITH SOME VEGETABLES FOR ECONOMIC PRODUCTIVITY

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ABSTRACT

This study was carried out in a Private Farm at Mashtool El-Souk, Sharkia Governorate during 2007/2008 and 2008/2009 seasons to investigate the effect of intercropping of garlic, pepper or snap bean with strawberry on vegetative growth, quality and yield of the studied crops in the mixed intercropping, comparing with the solitary plantings of these crops examining some competition indices in these intercropping systems and to evaluate the systems for better management of resources to obtain less competition among plants, higher productivity, sustainability, and economic value. The results indicated that all sole crops had more vigorous vegetative growth and yield components than intercropping systems. Different intercropping systems compared with sole crop systems did not affect some fruit chemical characteristics of these crops. Competition indices pointed out that strawberry appeared to be the dominant crop in strawberry/snap beans and strawberry/garlic cropping systems. This indicates that strawberry grown in association with these two crops utilized the resources more aggressively than the respective intercrops which appeared to be dominated. Among the intercrops, pepper proved to be more competitive while garlic and snap beans exhibited almost similar competitive behavior.

Key words: Intercropping, Strawberry, Garlic, Pepper, Snap beans, Vegetative growth, Yield, Competition indices.

INTRODUCTION

The Egyptian population is progressively increasing and the cultivated area diminishes or even slowly widens. This situation necessitates maximizing the utilization of the cultivated area. Farmers are developing different crop production systems to increase productivity and sustainability since ancient times. In this respect, intercropping is one of the possibilities for increasing the usage of the cultivated land and is considered as one of the cropping systems to increase productivity and sustainability. Intercropping is defined as the growing of two or more crops simultaneously on the same area of land (Andrews and Kassam, 1976). The crops are not necessarily sown at exactly the same time, but they are usually simultaneous for a substantial part of their growing periods. Intercropping has been long practiced in many parts of the world (Francis, 1986), as it sometimes offers a higher land utilization efficiency (Willey, 1979), efficient acquisition of nutrients (Stern, 1993, and Morris and Garrity, 1993a), effective use of water resources (Morris and Garrity, 1993b), and reduces accumulation of NO_3–N in the soil profile (Stuelpnagel, 1993) or N input (Exnern *et al.*, 1999). It continues to be widely employed not only in tropical regions (Vandermeer, 1989), but also in temperate regions.

In many regions of Egypt, intercropping is becoming popular day by day especially among small farmers as it offers the possibility of yield advantage and low farm income relative to sole cropping. Intercropping of some vegetable crops, such as garlic, pepper, or snap bean with strawberry has been noticed in some regions of some strawberry cultivated regions, such as Mashtool El-Souk, especially in frigo planting system for local consumption. Hence there is a need to explore its feasibility and other related agro-economic aspects for these intercropping systems.

Competition among mixtures is thought to be the major aspect affecting the growth and yield of the species used in intercropping systems (Caballero *et al.*, 1995 and Carr *et al.*, 2004).

Plant growth of strawberry was unaffected when intercropped with onion, garlic, lettuce or carrot (Ali, 1999). Similar results were obtained for cowpea when intercropped with cucumber (Kassem, 1991), for tomato when intercropped with okra or cowpea (Olasantan, 1991), and for taro when intercropped with jew's mallow or snap bean

(Fattallah and Gawish, 1997). In these studies, the growth of the companion crops was reduced (Fattallah and Gawish, 1997, Ali, 1999, and El-Miniawy *et al.*, 2007). However, Srinivasan and Veresh (1985) found that a significant increase in vegetative growth of cabbage was observed when intercropped with tomato. Also, intercropping with strawberry caused some phenotypic alteration such as increasing height and growth habits of broad bean (Karlidag and Yildirim, 2007).

No significant variation in yield of strawberry was observed when intercropped with onion, garlic, lettuce or carrot (Ali, 1999), or with summer squash, pickling cucumber, musk melon or bell pepper (Duval, 2005), with broad bean (Karlidag and Yildirim, 2007), with cucumber, summer squash or muskmelon (Santos *et al.*, 2008), or with lettuce, radish or onion (Karlidag and Yildirim, 2009). However, Ali (1999) found that yield of onion and garlic was decreased when intercropped with strawberry, while yield of lettuce and carrot did not affect by intercropping. Also, there were no significant reductions in pod numbers, pod weight per plants and total yield of intercropped broad bean with strawberry (Karlidag and Yildirim, 2007).

Concerning fruit quality, Ali (1999) found that fruit size of strawberry significantly reduced by intercropping with onion, garlic, lettuce or carrot, while no significant differences were found in content of vitamin C, acidity and soluble solids content of fruits. Fruit quality of the companion crop was unaffected. Similarly, the chemical characteristics such as ascorbic acid, total soluble solid, and titratable acidity of strawberry fruits were not significantly affected by intercropping neither with broad bean (Karlidag and Yildirim, 2007) nor with lettuce, radish or onion (Karlidag and Yildirim, 2009).

As for the effect of intercropping on weed control, many authors reported that intercropping reduced the number and weight of weeds (Masresha, 2003, Olasantan and Bello, 2004 and Saudy and El-Metwally, 2009).

Also, a number of indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantage, and intercropping advantage have been proposed to describe and evaluate the competition among species and also economic advantages of each intercropping system (Agegnehu *et al.*, 2006, Banik *et al.*, 2006, Dhima *et al.*, 2007). In Egypt however, no systematic research work has been done so far to explore the

competitive behavior of component crops in different intercropping systems of strawberry with other vegetable crops.

Therefore, the objectives of the present study were (i) to investigate the effect of intercropping of garlic, pepper or snap bean with strawberry on vegetative growth, quality and yield of each crop in the mixed intercropping, comparing with the solitary plantings of these crops, (ii) to examine some competition indices in these intercropping systems and, (iii) to evaluate the systems for better management of resources to obtain less competition among plants, higher productivity, sustainability, and economic value.

MATERIALS AND METHODS

Experimental site and cultivars

This study was carried out in a Private Farm at Mashtool El-Souk, Sharkia Governorate during 2007/2008 and 2008/2009 seasons to compare the solitary cropping of strawberry, garlic, pepper or snap beans with the intercropping of these crops with strawberry and study their effects on vegetative growth, yield and quality of these crops. The main crop in this work is strawberry *(Fragaria x ananassa* cv. Festival), meanwhile, the intercropped crops were garlic *(Allium sativum* cv. Balady), pepper *(Capsicum annum* cv. Balady) and snap beans *(Phaseolus vulgaris* cv. Tema).

Experimental design

The treatments included four sole-cropping systems (strawberry, garlic, pepper, or snap beans), and three intercropping systems (garlic with strawberry, pepper with strawberry, or snap beans with strawberry). These treatments were arranged in a randomized complete block design with three replicates. The plot area was 8.4 m^2 and included 4 rows (each was 3 meter in length and 70 cm in width).

Strawberry plants were planted on September 25th in both growing seasons with cold-stored (frigo) transplants of Festival cultivar. Plants were 30 cm apart. In the same time, the cloves of garlic were sown. After that, the pepper transplants were planted on January 7th in both seasons. Then the seeds of snap beans were sown on January 20th in both seasons. Sole crops were planted on one side of the row for strawberry, pepper and snap beans while garlic was planted on two sides of the row at 15 cm apart.

All agricultural practices of cultivation were performed as recommended by the Egyptian Ministry of Agriculture for each crop in sole-cropping systems or for strawberry in intercropping systems. The soil texture was characterized as clay loamy soil.

Data recorded

Vegetative growth

A random sample of ten plants from the two inner rows of each experimental plot was taken at 45 days after planting of strawberry, pepper and snap beans, and at 120 days after planting of garlic for vegetative growth data. Plant height (cm) and number of leaves/plant were recorded. Leaf area (cm^2) was using a leaf area measuring device (LICOR LI-3100). The plants were removed with a shovel, to prevent damage to the root system. The excess soil attached to the roots was carefully removed. In the laboratory, the plants were washed and plant fresh weight was recorded. The plants were dried in an oven at 70°C until constant weight to record the plant dry weight.

Yield components

For strawberry, pepper and snap beans, fruits were harvested at 2–3 day intervals during the growing season, counted, and weighed to record number of fruits/plant, average fruit weight and total yield/plant. Total yield/feddan was calculated. The early yield of strawberry was determined as weights of all harvested fruit during the first five harvests and average early yield/feddan was calculated. For garlic, average weight of bulb, average weight of clove and number of cloves/bulb were recorded. Total yield/feddan was calculated.

Fruit quality

For strawberry, soluble solids content (SSC) was determined using a hand refractomer. Titratable acidity (%) and ascorbic acid content (mg ascorbic acid/100 g fresh berries) were determined according to A.O.A.C. (1995).

For garlic, soluble solids content (SSC) of cloves was determined by a hand refractomer.

For pepper, soluble solids content (SSC) was determined using a hand refractomer. Ascorbic acid content (mg ascorbic acid/100 g fresh fruit) was determined according to A.O.A.C. (1995). Flesh thickness (mm) was measured using a caliper.

For snap beans, fiber content percentage was determined according to Chapman and Pratt (1961).

Associated weeds

Weeds were hand pulled from one square meter of each plot allover the growing season of each crop for sole crops and allover the growing season of the intercropped strawberry for the different intercropping systems. Fresh weight of weeds was recorded.

Competition indices and monetary advantage

The benefit of planting patterns and the effect of competition between the four crops used in this study were calculated using different competition indices.

The land equivalent ratio (LER) was used as the first criterion for mixed systems. In particular, LER verifies the effectiveness of intercropping for using the resources of the environment compared to sole cropping (Dhima *et al.*, 2007). When LER is greater than 1, the intercropping favours the growth and yield of the species. In contrast, when LER is lower than 1, the intercropping negatively affects the growth and yield of plants grown in mixtures (Caballero *et al.*, 1995, Dhima *et al.*, 2007). The LER values were calculated according to the formula described by Willey and Osiru (1972) as following:

$$LER = LER_{strawberry} + LER_{intercropped\ crop}, \text{ where}$$
$$LER_{strawberry} = Y_{si} / Y_s, \text{ and}$$
$$LER_{intercropped\ crop}$$
$$LER_{garlic} = Y_{gi} / Y_g$$
$$LER_{pepper} = Y_{pi} / Y_p$$
$$LER_{snap\ beans} = Y_{bi} / Y_b$$

where Y_{si} , Y_{gi} ,Y_{pi} and Y_{bi} are the yields of strawberry, garlic, pepper and snap beans as intercrops, respectively, and Y_s , Y_g , Y_p and Y_b are the yields of strawberry, garlic, pepper and snap beans as sole crops, respectively.

The second index was aggressivity (A) which is often used to determine the competitive relationship between two crops used in the mixed cropping (Willey, 1979). The aggressivity was formulated according to Dhima *et al.* (2007) as fallows:

$$A_{strawberry} = (Y_{si} / Y_s \times Z_{si}) - (Y_{is} / Y_i \times Z_{is}), \text{ and}$$
$$A_{intercropped\ crop} = (Y_{is} / Y_i \times Z_{is}) - (Y_{si} / Y_s \times Z_{si})$$

where Z_{si} and Z_{is} were the proportions of strawberry and corresponded intercropped crop in the mixture, respectively. For strawberry example; if $A_{strawberry} = 0$, both crops are equally competitive, if $A_{strawberry}$ is positive, then strawberry is dominant, if $A_{strawberry}$ is negative, then strawberry is weak.

The third coefficient was the relative crowding coefficient (K) which is a measure of the relative dominance of one crop over the other in a mixture (Banik *et al.*, 2006). The K was calculated as:

$$K = (K_{strawberry} \times K_{intercropped\ crop}), \text{ where}$$
$$K_{strawberry} = Y_{si} \times Z_{is} / ((Y_s - Y_{si}) \times Z_{si}), \text{ and}$$
$$K_{intercropped\ crop} = Y_{is} \times Z_{si} / ((Y_i - Y_{is}) \times Z_{is}).$$

When the value of K is greater than 1, there is a yield advantage; when K is equal to 1, there is no yield advantage; and, when it is less than 1.00, there is a disadvantage (Dhima *et al.*, 2007).

Also, competitive ratio (CR) is another way to assess competition between different crops. The CR gives more desirable competitive ability for the crops and is also advantageous as an index over K and AYL (Dhima *et al.*, 2007). The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops in which they are initially sown. The CR index was calculated as:

$$CR_{strawberry} = (LER_{strawberry} / LER_{intercropped\ crop})(Z_{is} / Z_{si}), \text{ and}$$
$$CR_{intercropped\ crop} = (LER_{intercropped\ crop} / LER_{strawberry})(Z_{si} / Z_{is}).$$

The next index was the actual yield loss (AYL) index, which gave more accurate information about the competition than the other indices between and within the component crops and the behaviour of each crop in the intercropping system, as it is based on yield per plant (Banik *et al.*, 2000). The AYL is the proportionate yield loss of intercrops in comparison to the respective sole crop, i.e. it takes into account the actual sown proportion of the component crops with its sole stand. In addition, partial $AYL_{strawberry}$ or $AYL_{intercropped\ crop}$ represent the proportionate yield loss of each crop when grown as intercrops, relative to their yield in sole planting (Dhima *et al.*, 2007). The AYL was calculated according to Banik (1996) as follows:

$$AYL = AYL_{strawberry} + AYL_{intercropped\ crop}, \text{ where}$$
$$AYL_{strawberry} = ((Y_{si} / X_{si}) / (Y_s / X_s)) - 1, \text{ and}$$
$$AYL_{intercropped\ crop} = ((Y_{is} / X_{is}) / (Y_i / X_i)) - 1$$

where X_{si} and X_{is} represent the sown proportion of intercrop strawberry with corresponded intercropped crop, and corresponded intercropped crop with strawberry, respectively. The AYL can have positive or negative values indicating an advantage or disadvantage remained in intercrops when the main aim is to compare yield on a per plant basis.

Additionally, intercropping advantage (IA) was calculated using the following formula (Banik *et al.*, 2000):

$$IA_{strawberry} = AYL_{strawberry}\, P_{strawberry}, \text{ and}$$
$$IA_{\text{intercropped crop}} = AYL_{\text{intercropped crop}}\, P_{\text{intercropped crop.}}$$

where $P_{strawberry}$ and $P_{\text{intercropped crop}}$ are the commercial value of strawberry (the farm gate price of ton for strawberry is 1250 Egyptian pounds as the average price for the two growing seasons) and intercropped crops (the farm gate price of ton for garlic is 1280 Egyptian pounds, for pepper is 795 Egyptian pounds and for snap beans is 1000 Egyptian pounds, respectively as the average price for the two growing seasons). The prices were obtained from the Central Administration of Agricultural Economics and Statistics.

Finally, the monetary advantage index (MAI) was calculated since none of the above competition indices provides any information on the economic advantage of the intercropping system. The calculation of MAI was as follows (Ghosh, 2004):

$$MAI = (\text{value of combined intercrops})\,(LER-1) / LER;$$

The higher the MAI value, the more profitable the cropping system is.

Data analysis

Data were subjected to the analysis of variance with SAS statistical package (1998). A combined analysis of variance over 2 years was performed for the growth, yield parameters, competitions indices and monetary advantages using Bartlett's test to check for homogeneity of variances of each parameter among years. Means were separated using least significance difference (LSD) at $P = 0.05$.

RESULTS AND DISCUSSION

Effect of intercropping on vegetative growth

In general, data presented in Table 1 revealed that vegetative growth characters were significantly affected by intercropping. All sole crops had more vigorous vegetative growth than intercropping systems.

Vegetative growth of strawberry: sole planting of strawberry or intercropping of snap beans with strawberry gave the highest values of plant height, number of leaves/plant and leaf area without significant differences. Strawberry when intercropped with snap beans exhibited more fresh and dry plant weight than sole strawberry planting. The lowest values of studied characters were obtained from intercropping of garlic or pepper with strawberry without significant differences.

Vegetative growth of garlic: vegetative growth of garlic was reduced when intercropped with strawberry compared with the sole crop.

Vegetative growth of pepper: intercropping of pepper with strawberry reduced significantly plant height, number of leaves/plant and fresh and dry plant weight. There was no significant difference in leaf area between the sole crop and intercropped pepper with strawberry.

Vegetative growth of snap beans: intercropping of snap beans with strawberry reduced significantly the vegetative growth of snap beans when compared with the sole crop.

These phenotypic alternations in some vegetative growth characters are due to the competition among mixtures which is thought to be the major aspect affecting the growth of the species used in intercropping systems (Caballero *et al.*, 1995, and Carr *et al.*, 2004). Such results are similar to those obtained by Srinivasan and Veresh (1985), Fattallah and Gawish (1997), Ali (1999), El-Miniawy *et al.* (2007) and Karlidag and Yildirim (2007).

Table 1: Effect of sole crops and intercropping of garlic, pepper and snap beans with strawberry on vegetative growth of the different crops (combined analysis of two growing seasons).

Cropping systems	Plant height (cm)	Number of leaves/plant	Plant fresh weight (g)	Plant dry weight (g)	Leaf area (cm^2)
Strawberry					
Sole strawberry	13.80	13.20	45.54	14.25	45.61
Strawberry with garlic	10.98	12.30	23.27	6.28	32.26
Strawberry with pepper	11.16	12.00	23.47	5.60	32.26
Strawberry with snap beans	13.71	12.20	60.27	18.51	44.12
L.S.D at 0.05	2.30	Ns	2.71	0.81	3.04
Garlic					
Sole garlic	89.47	9.40	130.04	41.17	109.87
Garlic with strawberry	79.33	7.30	78.42	28.70	69.50
L.S.D at 0.05	6.14	0.50	4.33	5.48	12.87
Pepper					
Sole pepper	46.45	79.60	122.22	17.15	20.00
Pepper with strawberry	40.82	68.80	115.44	13.60	18.50
L.S.D at 0.05	3.36	1.70	1.48	0.85	Ns
Snap beans					
Sole snap beans	48.43	48.00	169.50	49.07	38.15
Snap beans with strawberry	39.08	35.00	99.91	24.47	27.33
L.S.D at 0.05	3.98	5.75	42.84	3.54	5.73

Ns Non significant

Effect of intercropping on yield and quality

Yield and quality of strawberry: data from Table 2 revealed that the highest number of fruits/plant, average fruit weight, early yield and total yield per plant and feddan, without significant differences, were obtained from sole planting of strawberry and snap beans with strawberry while the lowest values for these studied characters were obtained from intercropping of garlic or pepper with strawberry. The reason for unaffected strawberry yield in strawberry/snap beans may be attributed to nitrogen fixing ability of snap beans (Chen *et al.*, 2004) and extensive root system of strawberry. Also, the unaffected strawberry yield in strawberry/snap beans may be due to the dissimilarity of root distribution for both crops and consequently low

competition between these crops since Wilson (1988) found that root competition had a greater effect than shoot competition on plant growth and resource capture. In addition, there were no significant differences in soluble solids content and titratable acidity between the sole planting and intercropping system. Our obtained results agree with those obtained by Ali (1999), Duval (2005), and Karlidag and Yildirim (2007) and (2009).

Table 2: Effect of intercropping of pepper, garlic and snap beans with strawberry on yield and quality of strawberry fruits (combined analysis of two growing seasons).

Cropping systems	No. of fruits/ plant	Average fruit weight (g)	Early yield		Total yield		Soluble solids content (%)	Titratable acidity (%)	Ascorbic acid content (mg /100 g fw)
			plant (g)	feddan (ton)	plant (g)	feddan (ton)			
Sole strawberry	38.00	13.67	102.33	2.05	519.46	10.39	7.08	0.35	76.43
Strawberry with garlic	29.30	12.00	90.83	1.82	351.60	7.03	7.00	0.26	67.98
Strawberry with pepper	27.10	11.00	82.50	1.65	298.10	5.96	7.05	0.23	68.73
Strawberry with snap beans	37.30	12.67	101.17	2.02	472.59	9.45	7.27	0.33	73.10
L.S.D at 0.05	4.80	1.34	7.32	0.16	77.63	1.55	Ns	Ns	2.01

Ns Non significant

Yield and quality of garlic: data presented in Table 3 showed that sole planting of garlic gave higher average weight of bulb, number of cloves/bulb and higher yield per plant and per feddan compared to intercropping of garlic with strawberry. There was no significant difference in average weight of clove between a sole planting and intercropping system. Garlic cloves obtained from sole planting had more soluble solids content than those obtained from intercropping garlic with strawberry. Such results are similar to those obtained by Ali (1999).

Table 3: Effect of intercropping of garlic with strawberry on yield and quality of garlic (combined analysis of two growing seasons).

Cropping systems	Average weight of bulb (g)	Average weight of clove (g)	No. of cloves/ bulb	Total yield/plot* (kg)	Total yield/ feddan (ton)	Soluble solids content (%)
Sole garlic	112.03	4.29	15.40	17.92	8.96	31.00
Garlic with strawberry	78.33	2.73	11.70	3.13	1.57	28.00
L.S.D at 0.05	8.72	Ns	1.60	4.30	2.15	2.92

* Plot area = 8.4 m^2 Ns Non significant

Yield and quality of pepper: sole planting of pepper gave higher number of fruits/plant, higher fruit weight, and higher yield per plant and per feddan compared to intercropping of pepper with strawberry. There were no significant differences in soluble solids content, ascorbic acid content and flesh thickness of pepper fruits between a sole planting and intercropping systems (Table 4). These results agree with those of Ali (1999).

Table 4: Effect of intercropping of pepper with strawberry on yield and quality of pepper fruits (combined analysis of two growing seasons).

Cropping systems	No. of fruits/ plant	Average fruit weight (g)	Total yield/ plot* (k.g)	Total yield/ feddan (ton)	Soluble solids content (%)	Ascorbic acid content (mg/100 g fw)	Flesh thickness (mm)
Sole pepper	19.00	39.08	29.70	14.85	7.43	81.43	2.52
Pepper with strawberry	11.00	29.50	12.98	6.49	7.017	68.85	2.05
L.S.D at 0.05	3.30	6.55	5.56	2.78	Ns	Ns	Ns

* Plot area = 8.4 m^2 Ns Non significant

Yield and quality of snap beans: data from Table 5 showed that sole planting of snap beans gave higher number of pods/plant, higher pod weight, and higher yield per plant and per feddan compared to intercropping snap beans with strawberry. There was no significant difference in fibres content in snap beans fruits between a sole planting and intercropping system. These results coincide with those obtained by Ali (1999) and Karlidag and Yildirim (2007).

Table 5: Effect of intercropping of snap beans with strawberry on yield and quality of snap beans pods (combined analysis of two growing seasons).

Cropping systems	No. of pods/plant	Pod weight (g)	Total yield/plot* (kg)	Total yield/feddan (ton)	Fibres (%)
Sole snap beans	48.20	6.09	11.74	5.87	21.11
Snap beans with strawberry	35.30	4.45	6.28	3.14	21.57
L.S.D at 0.05	11.50	0.73	1.12	0.56	Ns

* Plot area = 8.4 m^2 Ns Non significant

These results obtained from yield and quality data are due to the competition among mixtures which is thought to be the major aspect

affecting the yield of the species used in intercropping systems (Caballero *et al.*, 1995, and Carr *et al.*, 2004).

Effect of intercropping on associated weeds

The results in Table 6 showed that sole snap beans and pepper recorded low values of fresh weight of weeds compared to growing garlic or strawberry alone. This may due to the longer growing seasons of strawberry and garlic than those of snap beans and pepper.

Regarding the effect of intercropping, the lowest fresh weight was recorded with mixed plantation of snap beans with strawberry and garlic with strawberry. Similar reductions in fresh weight of associated weeds grown within intercropped crops were noticed by Masresha (2003), Olasantan and Bello (2004) and Saudy and El-Metwally (2009). Intercrops compete with weeds for living space, light, nutrients and water. In addition, some intercrop species release allelopathic compound which limit the occurrence of weeds (Wanic *et al.*, 2005).

Table 6: Fresh weight of weeds during the growing season of each crop for sole crops and during the growing season of the intercropped strawberry for the different intercropping systems. (combined analysis of two growing seasons).

Cropping systems	Fresh weight of weeds (g)
Sole strawberry	1404.8
Sole garlic	1256.9
Sole pepper	1052.4
Sole snap beans	915.0
Garlic with strawberry	1035.0
Pepper with strawberry	1212.1
Snap beans with strawberry	968.7
L.S.D at 0.05	109.8

Competition indices and monetary advantage

Land equivalent ratio(LER): Table 7 showed that the partial LER of strawberry was more than that of intercrop in all intercropping systems with a maximum LER (0.91) when snap beans was intercropped with strawberry followed by strawberry/garlic cropping (0.68) and strawberry/pepper (0.57). Maximum partial LER of intercrop was recorded in snap beans (0.53). Combined maximum LER was obtained in strawberry/snap beans cropping (1.44). Low

value of total LER in strawberry/garlic intercropping system may be due to the reduced yield of garlic when intercropped with strawberry and this may be due to the reduced number of garlic plants in this pattern compared with sole garlic planting. Those results are consistent with the results of Mead and Willey (1980) and Moseley (1994) who reported the intercropping caused an increase in LER over sole cropping system.

Aggressivity (A): The competitive ability of the component crops in an intercropping system is determined by its aggressivity value. An aggressivity value of zero indicates that component crops are equally competitive. For any other situation, both crops will have the same numerical value, but the sign of the dominant species will be positive and that of dominated negative. The greater the numerical value, the bigger the differences between actual and expected yields. Data presented in Table 7 revealed that the component crops did not compete equally. A positive $A_{strawberry}$ value in strawberry/garlic pattern showed that strawberry was the dominant in this system. However, in strawberry/pepper and strawberry/snap beans intercropping systems, pepper and snap beans were dominated. Aggressivity value was the minimum for strawberry/pepper intercropping system, which indicated that pepper was the most competitive crop to strawberry. By contrast, garlic proved to be less competitive to strawberry. The reduced yield of garlic when intercropped with strawberry may be due to the reduced number of garlic plants in this pattern compared with sole garlic planting.

Table 7: Land equivalent ratio and aggressivity as affected by intercropping of garlic, pepper or snap beans with strawberry.

Intercropping systems	Land equivalent ratio (LER)			Aggressivity (A)	
	Strawberry	Intercrop	Total	Strawberry	Intercrop
Strawberry + garlic	0.68	0.18	0.86	0.50	- 0.50
Strawberry + pepper	0.57	0.44	1.01	- 0.45	0.45
Strawberry + snap beans	0.91	0.53	1.44	- 0.24	0.24

Relative crowding coefficient (K): The competitive effects and advantages of intercropping systems are also determined by the relative crowding coefficient. Each crop has its own relative crowding coefficient (K) (Willey, 1979). The component crop with higher ‘K’ is dominated. If `K’ of two species is equal, less or greater than one, it

means that the intercropping system has no advantage, disadvantage or advantage, respectively. According to the results of Table 8, all intercropping systems studied have yield advantage. In strawberry/garlic and strawberry/snap beans intercropping systems, strawberry appeared to be highly dominant as it had higher value of `K' than the intercrops in these two systems, while in strawberry/pepper cropping, pepper was dominated. It may be inferred that pepper as intercrop utilized the resources more competitively than garlic and snap beans. Among the intercropping systems, the maximum yield advantage was obtained from strawberry/snap beans as indicated by its maximum value of `K'.

Competitive ratio (CR): The competitive ratio is an important tool to know the degree with which one crop competes with the other. Higher CR values for strawberry than the intercrop in strawberry/garlic and strawberry/snap beans cropping systems indicated that strawberry was more competitive than the companion crops in these systems (Table 8). The competitive ratio was higher for pepper in strawberry/pepper system. These results suggest that among intercrops, pepper proved to be a better competitor than all other two intercrops when grown in association with strawberry. It is evident from the competitive ratio that garlic and snap beans are the most suitable crops for intercropping with strawberry.

Table 8: Relative crowding coefficient and competitive ratio as affected by intercropping of garlic, pepper or snap beans with strawberry.

Intercropping systems	Relative crowding coefficient (K)			Competitive ratio (CR)	
	Strawberry	Intercrop	Total	Strawberry	Intercrop
Strawberry + garlic	1.05	0.43	1.48	1.89	0.53
Strawberry + pepper	0.67	1.55	2.22	0.65	1.54
Strawberry + snap beans	5.03	2.30	7.33	0.86	1.16

Actual yield loss (AYL): Results of AYL showed that strawberry was more dominant than its companion crop in strawberry/garlic and strawberry/snap beans cropping systems as the partial AYL values of strawberry were positive in these systems whereas pepper more dominant than strawberry in strawberry/pepper cropping system as the partial AYL value of strawberry was negative (Table 9).

Intercropping advantages (IA): The IA is an indicator of the economic feasibility of intercropping systems. Partial IA values for strawberry were positive values in strawberry/garlic and strawberry/snap beans cropping systems. Maximum positive value for strawberry was recorded in strawberry with snap beans (475) followed by strawberry with garlic (37.50). Partial IA values for pepper and snap beans in strawberry/pepper and strawberry/snap beans systems were positive. Thus, these intercrops got a certain advantage due to intercropping with strawberry. Maximum partial IA value for intercrops was found in snap beans. Intercropping advantage values indicates the advantage of the intercropping systems as the total IA values were in positive in strawberry/pepper and strawberry/snap beans systems.

Monetary advantage index (MAI): Monetary advantage index values were positive which showed a definite yield advantage in strawberry/pepper and strawberry/snap beans systems compared to sole cropping. The highest MAI value (4569.0) was obtained from strawberry with snap beans. Whereas , the minimum MAI value (- 1757.8) was obtained from strawberry with garlic (Table 9).

Table 9: Actual yield loss, intercropping advantage and monetary advantage index as affected by intercropping of garlic, pepper or snap beans with strawberry.

Intercropping systems	Actual yield loss (AYL)			Intercropping advantage			MAI
	Strawberry	Intercrop	Total	Strawberry	Intercrop	Total	
Strawberry + garlic	0.03	- 0.47	- 0.44	37.50	-601.60	-564.1	-1757.8
Strawberry + pepper	- 0.13	0.32	0.19	- 162.50	254.40	91.90	1248.5
Strawberry + snap beans	0.38	0.62	1.00	475	620	1095	4569.0

CONCLUSION

In conclusion, strawberry appeared to be the dominant crop as indicated by its competition indices in strawberry/snap beans and strawberry/garlic cropping systems. This indicates that strawberry grown in association with these two crops utilized the resources more aggressively than the respective intercrops which appeared to be dominated. Among the intercrops, pepper proved to be more competitive while garlic and snap beans exhibited almost similar competitive behavior.

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تحميل الفراولة مع بعض الخضر للإنتاج الإقتصادي

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أجريت هذه الدراسة في مزرعة خاصة بمشتول السوق بمحافظة الشرقية خلال الموسمين 2008/2007 و 2009/2008 لدراسة تأثير تحميل الثوم أو الفلفل أو الفاصوليا مع الفراولة على النمو الخضري والجودة والمحصول لهذه المحاصيل في نظم التحميل ومقارنتها بالزراعات المنفردة مختبراً بعض العلاقات التنافسية في هذه النظم وكذلك تقييم هذه النظم للحصول على أقل تنافس بين النباتات وأعلى إنتاجية وعائد إقتصادي. أوضحت النتائج أن جميع الزراعات المنفردة أعطت نمواً خضرياً ومحصولاً أعلى من نظم التحميل. لم يؤثر التحميل على بعض الصفات الكيميائية لثمار هذه المحاصيل. العلاقات التنافسية أوضحت أن الفراولة في نظامي التحميل فراولة/فاصوليا و فراولة/ثوم أكثر كفاءة وإستغلالاً للموارد الطبيعية (الضوء والماء والغذاء) منه عند تحميل الفلفل مع الفراولة.