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Intercropping Lettuce (*Lactuca sativa*) with Pea (*pisum sativum*) and its Impact on the Growth, Yield and Nutritional Quality

Attallah, Shreen Y.[1]; M.H. Z. El-Dkeshy[1]; Manal A.H. Mhmoud[2] and Somia H. Ahmed[1]

[1]Vegetable Crops Department, Faculty of Agriculture, Assiut University, Assiut, Egypt
[2] Food science and technology Department, Faculty of Agriculture, Assiut University, Assiut, Egypt

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Abstract

A field experiment was carried out during the two successive seasons of 2017/18 and 2018/19. The aims of the experiment were to investigate the effect of different planting arrangement patterns: T_1 (3 pea: 1 lettuce), T_2 (2 pea: 1 lettuce), T_3 (1 pea:1 lettuce), T_4 (side pea: side lettuce) in addition to sole lettuce and sole pea (control) treatments regarding the growth, yield, and nutritional quality, along with the financial aspects of applying intercropping systems for lettuce and pea productivity. The obtained results revealed that, intercropping lettuce with pea was more effective than planting pea crop alone, as it increased the lettuce yield by 12.2%-37.7% and 27.7%- 60 % in the first and second seasons respectively according to the intercropping system applied. All intercropping treatments except for T_4 (side pea: side lettuce) treatment reduced the pea yield. The highest pea yields were produced by both sole pea andT_4 treatments, while the lowest pea yield was form T_3, in both seasons. T_3 treatment depressed pea pod yield to 60% of its mono-cropped yield. On the other hand, T_1 and T_2 treatments produced the highest yield for lettuce in both seasons. Intercropping lettuce with pea, led to an improvement in the protein percentage in pea. LER of pea/lettuce intercropping treatments were more than unit. Moreover, the highest values for both LER and MAI obtained fromT_1 treatment. Calculated "aggressiveness" suggested that all secondary crop treatments were more dominant than pea in all intercropping treatments. The intercropping system of 3pea:1 lettuce could be a gainful system to obtain the greatest efficiency of land.

Keywords: *Main crop, secondary crop, Quality, yield components, intercropping system.*

Introduction

In developing countries, because there is fast growing population than that of food production, it's necessary to extend the output of food production from cultivated limited lands (Yildirim, 2003). Intercropping, the practice of cultivating two or more crops within the same space at the same time (Klimek-Kopyra *et al.,* 2018), is an old and customary feature in traditional farming of small land holders that aims to match efficiently crop demands to the available growth resources and reduces the failure risk of that's liable to environmental and economic fluctuations. Intercropping of compatible plants is considering as a system, which having multi-dimensional advantages like encourage biodiversity, by providing a habitat for a spread of insects and soil organisms that will not be present during a single-crop environment. These organisms may provide crops valuable nutrients, like through nitrogen fixation and thus improved yield on sustained basis, effective use of land and other resources because it improved nutrients,water and radiation use efficiency (Joliffe,1997) , provide farmers with a variety of returns as growing more than one crop per unit area,produce greater yield with lower environmental impact compared with single cropping systems (Monzon *et al*., 2014), suppress weeds, combat pests and diseases and increasing agricultural production and reduction in cost of production will occure. Intercropping, not only is helpful in improving mobilization and uptake of micronutrients but also, affects the utilization of some minerals within the rhizosphere, like Ca and Mg (Inal *et al*., 2007).

Intercropping legume with non-legume crops gives rise to more efficient resource capture than corresponding sole crops and, increases efficiency of using land and other resources which lands up in higher biomass production and reduction of the cost of production. Legume as an intercrop can enhance crop yields (Mucheru *et al*., 2010). Leguminous plants are useful for their ability to fix atmospheric nitrogen. Peas, cowpeas, soybeans and faba beans are good nitrogen fixers that fix all their nitrogen needs from the soil (Lithourgidis *et al*., 2011). The biological nitrogen fixation of leguminous plants reduces the nitrogen fertilizer usage (Park *et al*., 2010), the soil is additionally replenished with nitrogen through decomposition of legume residues. Also, non-legumes plants may benefit through N-transfer from legumes (Fujita *et al*., 1990). Excessive use of inorganic fertilizers causes environmental damage thus, legumes grown in intercropping systems are considered as an alternate environmental-friendly way of introducing N (Fustec *et al*., 2010).

This study was carried out for intercropping lettuce with pea. Pea was used as the main crop while lettuce was used as an intercrop for 2 years. The reported work evaluates the efficiencies of pea and lettuce grown as sole crops and when lettuce plants intercropped with pea at different ratios during 2017-2018 and 2018-2019 seasons.

Pea is commonly utilized in intercropping systems. It enhances nitrogen level in soil and offers better yields and economic returns (Lithourgidis *et al.,* 2011). Pea occupies a prominent place among vegetables due to its high nutritive value, particularly proteins and other health building substances, like carbohydrates, calcium, and phosphorus (Kotlarz *et al*., 2011). The annual global production of pea is approximately 14.5 million tons (FAOSTAT, 2019).

Lettuce (*Lactuca sativa* L.) is considered in concert of the foremost popular vegetables worldwide. Since it's generally eaten raw, a greater amount of nutrients is obtained by the organism. It's also strongly recommended for human consumption for its health benefits (Kim *et al*., 2016). Lettuce contains several minerals important for human health like iron (Fe), calcium (Ca), phosphorus (P), magnesium (Mg), and potassium (K) and other health-promoting bioactive compounds (Riga *et al*., 2019). Beneficial health properties of lettuce have mainly been attributed to phytochemicals like phenolic compounds (López *et al*., 2014). Nutritional composition is affected greatly by environmental like, light, fertilizers, and growing conditions (Kim *et al*., 2016).

In line with studying the intercropping system, objectives of this study were to study the influence of different planting arrangement patterns regarding the growth, yield, and nutritional quality, along with the financial aspects of applying intercropping systems for lettuce and pea productivity.

Materials and Methods

Experimental site, soil characteristics, and Experimental design

To study the effect of planting pattern on yield and competitive indicators of pea and lettuce, a factorial experiment based on Randomized Complete Block Design was conducted with three replications at the Experimental Farm of of 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

In the present study, Pea (*Pisum sativum*) was planted at distance between lettuce hills on October17, 2017 and October 15, 2018, respectively. Healthy pea seeds were sown 7 cm apart on the northern side of the rows. Lettuce (*Lactuca sativa* var. Romaine) seedlings were planted on November 10, 2017, and November 8, 2018, at 30 cm within-row spaces. Every treatment plot consisted of two rows 70 cm apart and 3 meters long. Lettuce (*Lactuca sativa* var. Romaine) as secondary crop was intercropped with pea (*Pisum sativum* L., Master-B) as main crop in both seasons of the experiment. A constant density of lettuce is combined with a range of densities of pea plants. The experiment consisted of eighteen plots in total (six treatments and three replications). The treatments of the planting pattern included 4 levels of combination between lettuce and pea plants according to different pea densities i.e., T_1 (3 pea plants: 1 lettuce plant), T_2 (2 pea plants: 1 lettuce plant), T_3 (1 pea plant:1 lettuce plant), T_4 (side pea plants: side lettuce plants) in addition to sole lettuce and sole pea treatments. During soil preparation, 100 kg/fed superphosphate (15.5% P_2O_5) were added, 200 kg from ammonium nitrate (33.5%N), 100 kg/fed superphosphate and 100 kg/fed potassium sulphate were applied as doses after three weeks from transplanting and at flowering stage. Agricultural practices of irrigation, pest control, disease control, etc., were applied as recommended for pea production.

Data collection and analysis:

Data collection for pea crop

a. Yield and its components

Pod length (cm) and pod diameter (cm) was measured using a Vernier clipper, number of seeds per pod were counted, average yield/ plant (g), and total yield from each plot were weighed, then total yield (ton/feddan) were calculated.

b. Nutritional quality measurements

The protein content of the dried samples was estimated as percent total nitrogen by the Micro-Kjeldahl method (AOAC, 2000) and then computed by multiplying the percent nitrogen using conversion factor 6.25. oil content, total ash and crude fiber were determined according to AOAC, (2000).

$$\textbf{Moisture content (g/100g)} = \frac{\textbf{Initial weight (g) - Final weight (g)}}{\textbf{Weight of the sample}} \times 100$$

$$\textbf{Oil content (g /100g)} = \frac{\textbf{Weight of ether extract}}{\textbf{Weight of sample taken.}} \times 100$$

$$\textbf{Ash content (g/100g sample)} = \frac{\textbf{Weight of the ash}}{\textbf{Weight of the sample}} \times 100$$

$$\textbf{Crude fibre (g/100g sample)} = \frac{\textbf{(100-(moisture*+fat)] x (We-Wa))}}{\textbf{wt. of sample taken (moisture and fat free)}}$$

We: pre weighed ashing dish Wa: weight of the dish after ashing

Carbohydrate (g/100 g) = 100 – [Protein (g) + Fat (g) + Fibre (g)+ Ash (g)]

The total phenolic content of every sample of lettuce–determined by Folin Ciocalteu method as described by Marinova *et al*., (2005) Total flavonoid content in lettuce extract was determined as described by Khanam *et al*., (2012).

Plant nutrient analysis was performed on plant consumable part (seeds). Total phosphorus content was determined by spectrophotometer (Jackson, 1967). The contents of Mg and Ca in the studied samples were determined by iCAP6200 (ICP-OES) Inductively Coupled Plasma Emission Spectrometry (Isaac and Johnson, 1985).

Data collection for lettuce crop

a. Vegetative growth and yield measurements

Vegetative parameters for five plants of lettuce in each plot were recorded: plant height (cm), number of leaves per plant, and plant weight (g) were measured. Yield was estimated in kg/feddan, then expressed as (ton/ feddan).

b. Nutritional quality measurements

Total soluble solids percentage (TSS%) was determined using a hand refractometer. Protein, oil, crude fiber, total phenolic and total flavonoids were estimated as mentioned previously. Computation of carbohydrate: Carbohydrate content was calculated by differential method (AOAC, 2000). Plant nutrient analysis was performed on plant consumable part (leaves). The contents of K, Mg and Ca in the studied samples were determined by iCAP6200 (ICP-OES) Inductively Coupled Plasma Emission Spectrometry (Isaac and Johnson, 1985). Total phosphorus content was determined by spectrophotometer (Jackson, 1967).

Intercropping efficiency parameters

a. Land equivalent ratio (LER)

Land equivalent ratio (LER) was calculated according to Willey (1979) in order to compare the productivity of intercropping systems against monocrop, where

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, shows that intercropping is advantageous and more effective regarding productivity compared to sole cropping (Vandermeer, 1989).

b. Aggressiveness values

Aggressiveness values were calculated by the following equations according to (McGilchrist, 1965) where:

Aggressiveness for main crop = (intercropping yield of main crop/ expected yield of main crop)- (intercropping yield of second crop/ expected yield of second crop).

Aggressiveness for second crop = (intercropping yield of second crop/ expected yield of second crop)- (intercropping yield of main crop/ expected yield of main.

The expected yield = yield of monocrop × the fraction of the area occupied by intercropping (0.5 for the 2 crops)

c. 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 (Willey, 1979):

$$\text{MAI} = \frac{\textbf{Value of combined intercrops x (LER – 1)}}{\textbf{LER}}$$

In Egyptian pound lettuce price was 3.5-4.5 L.E./plant, pea was 10 L.E./kg for yield as an average market price over the two seasons of study (**Bulletin of Statistical Cost Production and Net Return, 2017**)

Statistical analysis

The experimental data were statistically analyzed using 1998-2004 CoHort Software, version 6.303 (798 Lighthouse Ave. PMB 320, Monterey, CA, 93940, USA). Means of the treatments were compared by Duncan's multiple range tests at 5% probability level.

Results and Discussion

Effect of intercropping systems on pea yield and yield components

The results in Table 1 showed the effect of intercropping systems on the pea yield and its components. However, the differences between intercropping treatments were found statistically significant for all the parameters studied (Table 1). The significant longest pod length was obtained when intercropping pea with lettuce. While the significant decrease in pod length, pod diameter, and the number of seeds per pod were recorded when pea was grown alone (control treatment). Although non-significant differences in dry matter percentage parameter between intercropping treatments and the control were found in the first season but a slight decrease in the second season was observed when pea was intercropped with lettuce. The values of dry matter percentage decreased significantly when pea was intercropped with lettuce by the ratio of intercropping pea with lettuce by the ratio of 1 pea plant: 1 lettuce plant (T_1).

Regarding total yield per plant in pea crop, T_3 (1 pea plant:1 lettuce plant) treatment produced the maximum values for yields per plant with an average,140.23 and 155.16 g/plant in the two seasons respectively. However, there were no significant differences betweenT_3 (1 pea plant:1 lettuce plant) and T_2 (2 pea plants:1 lettuce plant) in yields per plant parameter in the two seasons of study. Intercropping pea with lettuce by the ratio of 1 pea plant: 1 lettuce plant (T_1) produced the lowest value for yields per plant with an average, 117.86 and 125.53 g/plant in the two seasons respectively. These results may be due to the less competition between crop species than that between plants of the same species (Vandermeer, 1989). The highest total pea yields/feddan were achieved in treatments of sole cropping of pea with 3.039 and 3.25 ton/ feddan and T_4 (Side pea: side Lettuce) with 3.018 and 3.212 ton/ feddan in the two seasons, respectively. While the least pea yield was obtained from the treatment of T_3 (1 pea plant: 1 lettuce plant) as the number of pea plants was the lowest in this treatment. According to the results, it seems that by increasing plant density, the maximum yield in the intercropping system will happen. Intercropping systems may lead to increased yield either of main or both crops (Prasad and Mohan, 1995) as compared to mono cultivation. However, it may result in a reduced total yield of one (Egbe and Bar, 2010) or both crops (Ghosh *et al*., 2006). However, in intercropping systems, the economic return is more important than the yield.

Lettuce is considered as a moderate feeder vegetable and both pea and lettuce are shallow rooted, but pea can exploit available resources more efficiently, so the competition was moderate between two crops. Although, most of the fixed nitrogen by legume plants goes directly into the plant, some nitrogen can be transferred for neighboring non-legume plants through the soil (Walley *et al*., 1996). Pea plants can naturally add nitrogen to the soil. Soluble nitrogen is available as converted from the air by bacteria that live on the roots of pea plants. This process is known as nitrogen fixation, and it is the main reason why peas are beneficial to lettuce plants. Lettuce requires lots of nitrogen, which is conveniently supplied by pea plants. The supplementary of a nitrogen-fixing crop can help in obtaining greater productivity than in comparable sole crops. Also, during this process, the rhizobia and their legume hosts can synthesize and release different phytohormones such as IAA, riboflavin, gibberellins, ethylene, cytokinins and the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase that can stimulate plant growth (Sanjay *et al*., 2021). IAA is an important member of the auxin family that is responsible for controlling plant physiological processes, organizing cell enlargement and division (Shokri and Emtiazi, 2010). The cropping density had a great impact on the relative competitive strength of the studied crops. Increasing the number of pea plants from one to three give rise to greater yields or resource use. A similar result was found by Hemedi *et al.* (2008) who revealed that, the use of high mucuna density is efficient in stabilizing the maize-mucuna system (Hemedi *et al*., 2008).

Table 1. Effect of intercropping treatments of lettuce with pea on pod length(cm), pod diameter (cm), No. of seeds /pod, dry matter %, average yield /plant (g/pl) and total yield (ton/fed) of pea plant (main crop) cv. "master-B" in the growing seasons of 2017/2018 and 2018/2019 respectively.

Treatment	Pod length (cm)	pod diameter (cm)	no. of seeds /pod	dry matter %	average yield/plant (g/pl)	total yield (ton /fed)
	Season 1					
T_1 (3Pea:1Lettuce)	10.4 a	1.3 a	9. 767 a	81.7 a	117.86 c	2.52 b
T_2 (2 Pea:1Lettuce)	10.067 ab	1.267 a	9.1 a	81.9 a	130.86 ab	1.869 c
T_3 (1 Pea:1Lettuce)	9.867 ab	1.13 b	8.867 ab	77.46 a	140.23 a	1.125 d
T_4 (Side pea: side Lettuce)	9.76 b	1.23ab	8.033 bc	81.33 a	120.83 bc	3.018 a
sole pea (Control)	8.7 c	0.93 c	7.8 c	80.2 a	121.66bc	3.039 a
	Season 2					
T_1 (3Pea :1Lettuce)	11 a	1.333 a	9.667 a	79.16 ab	125.53 b	2.69 b
T_2(2 Pea:1Lettuce)	10.5 ab	1.267 a	9 ab	75.36 bc	141.1 ab	2.014 c
T_3 (1 Pea:1Lettuce)	10.16ab	1.233 a	8.66 bc	73.13 c	155.16 a	1.245 d
T_4 (Side pea: side Lettuce)	9.9 b	1.267 a	7.93 cd	77.06 abc	129.33 b	3.212 a
sole pea(Control)	8.66 c	1.03 b	7.2 d	80.033 a	130.1 b	3.25 a

Means within column followed by the same letter(s) are not significantly different at 0.05 level of probability.

Effect of intercropping systems on growth and yield of lettuce

This study evaluated the agronomic viability of intercropping lettuce (*Lactuca sativa* var. Romaine) with pea (*Pisum sativum* L., Master-B) without additional inputs of water and fertilizers on pea in an intercropping production system. The same amount of water and fertilizers was applied to the intercropping and nonintercropping plots based on the needs of the pea plants. Plant growth characteristics were compared between lettuce plants with and without intercropping. The heaviest weight of leaves and the highest number of leaves per plant were obtained by intercrooping system in both seasons of study (Table 2) as compared to sole lettuce (control) treatment. However, differences in plant height were detected in lettuce plants intercropped with pea crop. T_1 (3Pea :1 Lettuce) treatment gave the tallest plant as compard to the other intercropping treatments in both seasons of study (Table 2).

The highest significant total yield per feddan was obtained when planting lettuce with peas as T_1 (3Pea :1 Lettuce) and T_2(2Pea :1 Lettuce) treatments. However, sole lettuce plants gave the lowest yields in both seasons (Table 2). The higher biomass production is frequently due to the enhanced growth of the component non-legume. Because the non-legume is generally taller than the legume and can therefore intercept adequate solar radiation, biomass production of the non-legume is more closely related to improved N nutrition (Fujita *et al*., 1990). Also, Adeniyi, 2011 (Adeniyi, 2011) revealed that intercropping with legumes was most useful as it improves soil fertility leads to better yields and economic returns (Lithourgidis *et al*., 2011).

Table 2 showed that the effect of the associated pea crop on lettuce yield. Intercropping of pea with lettuce seems to have a beneficial effect on lettuce yield under all intercropping systems. Increases in intercropped lettuce yields over the yield of lettuce sole crop were ranged between 12.2% and 37.7% in the first season and between 27.7% and 60% in the second season of study. The trend indicates the following results: 1- an increase in yield of 37.7% as compared to its sole crop was obtained underT_1 (3Pea :1 Lettuce) , 2- an increase in yield of 33.4% compared to its sole crop such as in T_2(2Pea :1 Lettuce) treatment,3- an increase in yield of 21.3% compared to its sole crop such as in T_3(1Pea :1 Lettuce) treatment,and4-the increase in yield of was 12.2% in T_4 (Side peas :side Lettuce) treatment as compared to its sole crop (Table2). Similar results were obtained by Sharaiha, R and Gliessman,S.(1992) in their work on the effect of crop combination and row arrangement in the intercropping of lettuce with pea on yields. The increases in yields of lettuce as it was intercropped with peas could be due to the rapid growth and hence earlier harvesting of pea that gave less competition to the available resources. This situation creates wider spacing between plants of lettuce as they grow under different intercropping systems in addition to a beneficial effect on lettuce crop as a non-legume crop. Therefore, it was expected that a legume crop such as peas, which can fix atmospheric nitrogen since lettuce was transplanted after pea by 25 days. This fact has been pointed out by many researchers such as (Willey, R. 1979; Sharaiha, R.and Kluson, R. 1994). However, the results from this study showed that lettuce grown with pea gave different responses in yield according to the number and the plant position of pea in row crop. Differences in yield could be attributed to the different microenvironment created by each intercropping system.

Table 2. Effect of intercropping treatments of lettuce with pea on leaves fresh weight (g), plant height (cm), number of leaves, and total yield (ton/fed) of lettuce plants (secondary crop) cv. "romaine" in the growing seasons of 2017/2018 and 2018/2019 respectively.

Treatment	Leaves fresh weight (g)	Plant height (cm)	Number of leaves	Total yield (Ton / fed)
	Season 1			
T_1 (3Pea :1 Lettuce)	1.503 a	54.333 a	90.083 a	12.068 a
T_2 (2 Pea :1 Lettuce)	1.456 ab	50.333 ab	84.85 a	11.688 ab
T_3 (1 Pea :1 Lettuce)	1.324 bc	46 bc	73.087 b	10.63 bc
T_4 (Side pea: side lettuce)	1.225 cd	41.767 c	77.777 b	9.827 cd
sole Lettuce (Control)	1.091 d	42.667 c	57.21 c	8.76 d
	Season 2			
T_1 (3Pea :1 Lettuce)	1.433 a	46.667 a	79.333 a	11.157 a
T_2 (2 Pea :1 Lettuce)	1.338 a	40.333 b	78.333 a	10.715 a
T_3 (1 Pea :1 Lettuce)	1.147 b	39.333 b	69 b	9.022 b
T_4(Side pea: side lettuce)	1.123 b	39 b	76.667 a	8.873 b
sole Lettuce (Control)	0.88 c	38.333 b	53.667 c	6.948 c

Means within column followed by the same letter(s) are not significantly different at 0.05 level of probability.

Effect of intercropping systems on nutritional quality of pea

Regarding the percentage of protein, a significant increase was noticed in all treatments as compared to the control treatment. The T_2 (2pea: 1lettuce) treatment achieved the highest values for protein in the two seasons. For the oil contents in the first season, T_3 treatment (1pea: 1lettuce) recorded the highest value (2.59%), followed by the control (2.36%) while, in the second season, control treatment had the highest value in oil (1.50%). Also, it is clear from Fig.1 that there was a significant increase in ash values for all intercropping treatments. However, ash content value was the lowest in the control treatment. For crude fiber contents as revealed in Fig.1., it is noticeable that T_2(2pea: 1lettuce) recorded the highest value for crude fiber in both seasons.

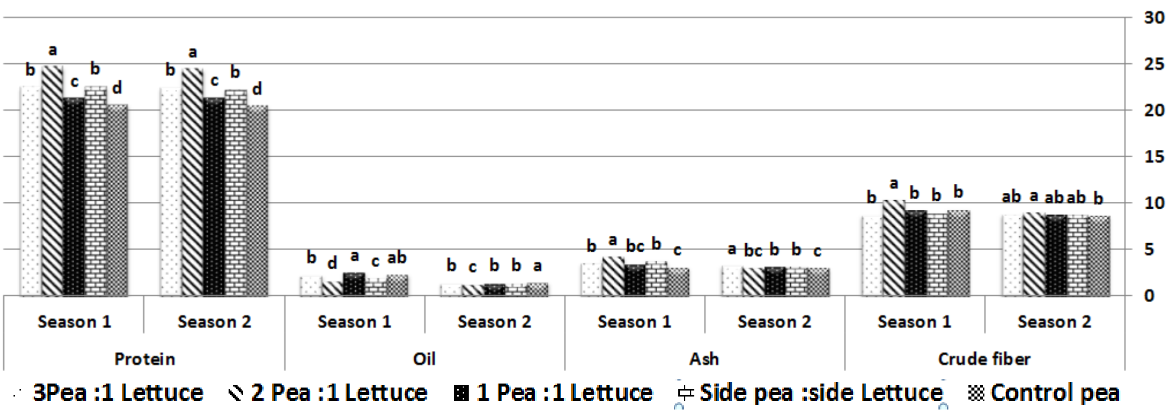

Fig.1. Effect of intercropping treatments on Protein, oil, ash, and curd fiber of green pea seeds (mg/100g dry weight) cv. "Master-B" in the2017/18 and 2018/19 growing seasons.

Fig.2. Shows that T_3 treatment (1pea: 1lettuce) gave the highest significant values for both total phenols in both seasons and total flavonoids in the 1st season only. While the difference between T_3 and control treatments for total flavonoids was not significant in the second season. T_1 (3pea: 1lettuce) treatment recorded the lowest significant values for total flavonoids contents in both seasons. This result may be due to the adverse relation between nitrogen availability and phenolic contents. Galieni *et al*., (2015) found that nitrogen availability seemed to reduce total polyphenols and antioxidant activity.

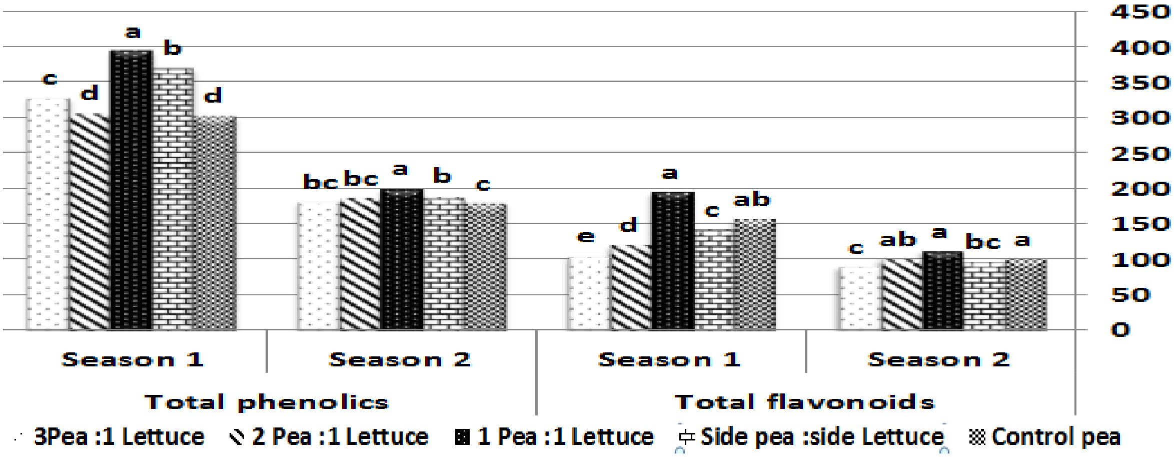

Fig. 2. Effect of intercropping treatments of pea with lettuce on Total phenolic and Total flavonoids of green pea seeds(mg/100g dry weight) cv. "Master-B" in the2017/18 and 2018/19 growing seasons

Effect on intercropping systems on plant nutrient analysis in green pea seeds

When looking at the amount of phosphorous in the pea samples, we notice that T_2(2 pea plants: 1 lettuce plant) recorded the highest significant values, followed by the control in both seasons, respectively. (Li *et al*., 2001) found that in intercropping systems, the interspecies root interactions play an important role in nutrient uptakes. Nitrogen-fixing legumes might have a role for the improvement of the efficiency of phosphates (van Beusichem, 1981). Also, Fried (1953) showed that the abilities of phosphorus uptake were favoured by leguminous plants. Most legumes, are dependent upon mycorrhizae for efficient P uptak (Giller and Cadisch, 1995). It is also noticed that there was a significant increase in calcium values for all intercropping treatments than the control treatment. T_4 (side pea: side lettuce) treatment achieved the highest significant values in both seasons. In the same way for the magnesium (Fig.3) content, where there was an increase in magnesium values for the intercropping treatments compared to the control in both seasons. T_1 (3Pea plants: 1 Lettuce plant) treatment recorded the highest significant values for magnesium in both seasons. However, there is limited literature on interspecies interaction effects due to intercropping systems on Ca and Mg uptake. Li, L. *et al*., (2004) found an increase in Ca concentration in chickpea for treatments with the interspecies root interactions and inorganic P supply.

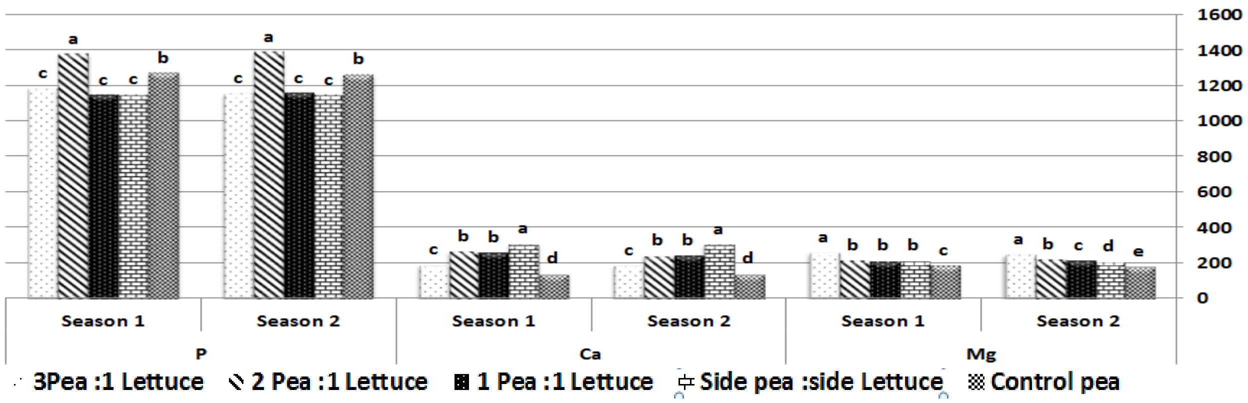

Fig.3. Effect of intercropping treatments on P, Ca, and Mg of green pea seeds (mg/100g dry weight) cv. "Master-B" in the 2017/18 and 2018/19 growing seasons.

Effect of intercropping systems on nutritional quality of lettuce

Results (Fig.4) revealed that, the crude fibers parameter, it is noticed that in the first season; intercropping treatments don't affect the percentage of fibers while, in the second season T_4(side pea: side lettuce) and control treatments recorded the highest significant values. The healthy properties are attributed to a large supply of fiber content (Liorach *et al*., 2008). There is a significant decrease in ash content of the intercropping treatments compared to the control in both seasons. Regarding oil, it is noticeable that the highest percentage of oil was in theT_4 (side pea: side lettuce) treatment. However, the difference betweenT_4 (side pea: side lettuce) and the control was not significant in the second season. The non-significant effect of legume intercrops on the oil content of maize was also reported by (Sultana *et al*., 2013).

It is clear from Fig.4 that there was a significant difference in the protein content in intercropping treatments as compared to the control. The highest percentage was achieved in T_4 treatment (side pea: side lettuce) in both seasons. The increase of the pea plants number compared to lettuce led to a significant decrease in the protein percentage asT_1 (3 pea plants: 1 plant lettuce) recorded the lowest value of protein as compared to the control. Regarding total soluble solids percentage (TSS%) content in lettuce leaves, all intercropping treatments showed an increase in TSS% values as compared to sole crop(control) treatment (Fig.4). T_1 (3Pea :1 Lettuce) andT_4 (Side pea: side Lettuce) treatments gave the highest significant value for (TSS%) content in lettuce leaves as compared to the other treatments in the first season of study, but in the second season, all intercropping treatments gave the highest values for TSS% but the difference was not significant as compared to sole crop (control) treatment. Zohair, 2016 found that the total soluble solid (TSS%) were significantly increased in lettuce leaves as a result for raising the N fertigation rates up to 150 kg ha-1. Also, This result may due to the improved the soil microbial biomass and activity (Zohair,2016).

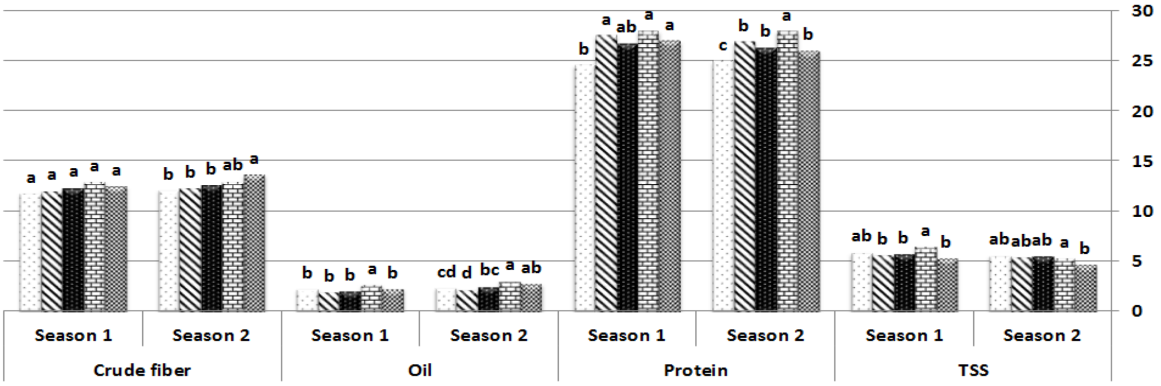

Fig.4. Effect of intercropping treatments of lettuce with pea on curde fiber, oil, protein and T.S.S. of lettuce plants (secondary crop) cv. "romaine" in the growing seasons of 2017/18 and 2018/019 respectively

It is clear from Fig.5 that the total carbohydrate content in lettuce leaf had a significant increase in all treatments except T_4 (pea side: lettuce side) in the first season. T_1(3pea: 1letuuce) gave the highest total carbohydrate content. The moisture content was found in closer ranges in the first and second seasons. Generally, the moisture percentage was increased in intercropping treatments as compared to the control.

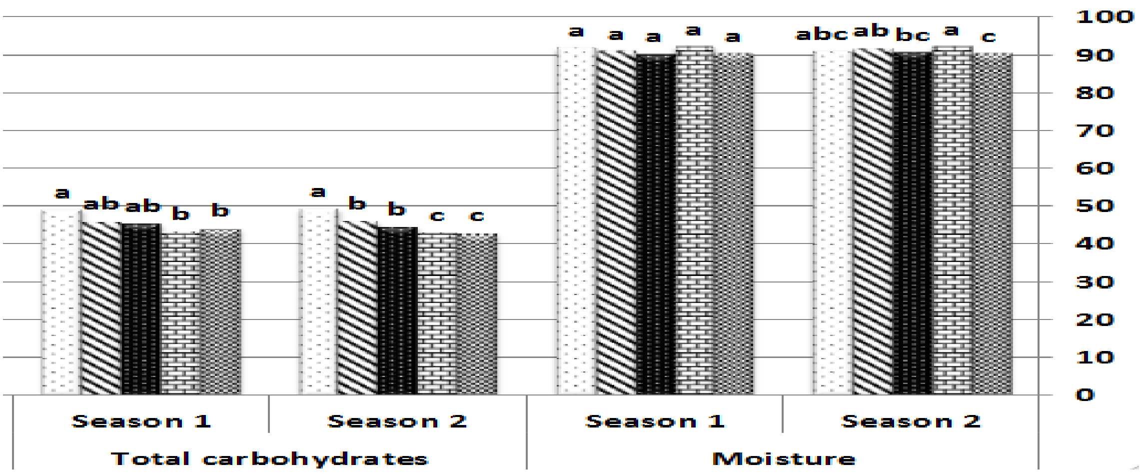

Fig.5. Effect of intercropping treatments of lettuce with pea on Total carbohydrates, and moisture of lettuce plants (secondary crop) cv. "romaine" lettuce leaves (g/100g dry weight) in the growing seasons of 2017/18 and 2018/19 respectively.

Regarding the content of phenolic and flavonoid contents for romaine lettuce leaves, Fig.6. shows that T_3 treatment (1pea: 1lettuce) gave the highest significant values for both total phenols in both seasons and total flavonoids in the 1st season only while the difference between T_3 and control treatments for total flavonoids was not significant in the second season. An increment in total flavonoids was found in T_1(3pea:1 lettuce) and T_4 (side: lettuce side) treatments in the second season (Fig.6).

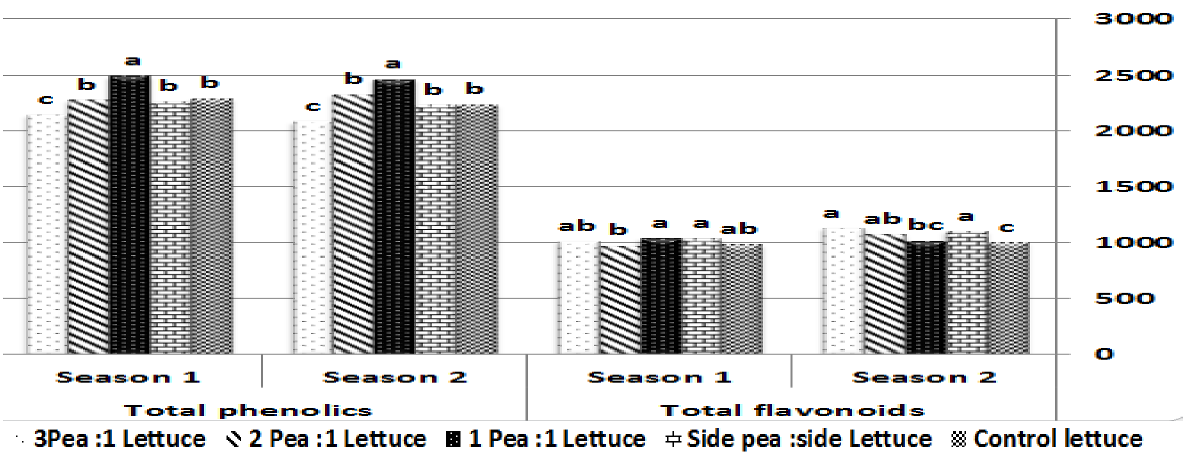

Fig.6. Effect of intercropping treatments of lettuce with pea on Total phenolic and Total flavonoids of lettuce plants (secondary crop) cv. "romaine" lettuce leaves (g/100g dry weight) in the growing seasons of 2017/18 and 2018/19 respectively.

Effect on intercropping systems on plant nutrient analysis in lettuce leaves

In the determination process of plant nutrient analysis in lettuce leaves, it was found that intercropping systems had an important effect on the amounts of elements. Fig.7 shows the mineral composition of romaine lettuce leaves. It was noted that the proportion of potassium, phosphorous, magnesium and calcium had a significant decrease in all intercropping treatments under study when compared with control in both seasons. Similar results were obtained by Stagnari *et al.* 2007 who found that, in spinach plants where K content was decreased by increasing N up to 200 kg ha-1(Stagnari *et al.*, 2007).

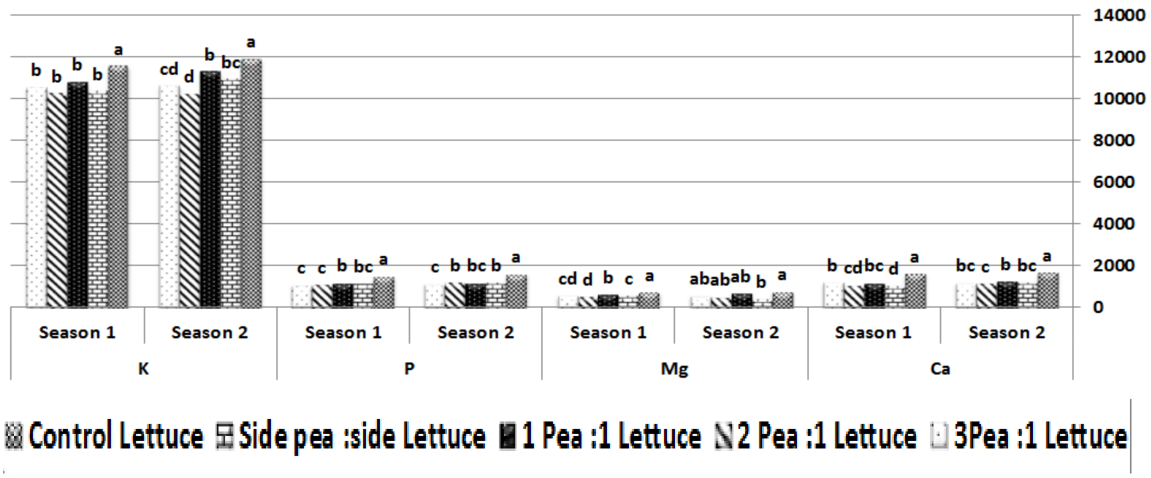

Fig. 7. Effect of intercropping treatments on K,P, Mg and Ca of lettuce plants (secondary crop) cv. "romaine" lettuce leaves (g/100g dry weight) in the growing seasons of 2017/18 and 2018/19 respectively

Intercropping efficiency parameters

Land equivalent ratio (LER)

The land equivalent ratio in intercropping treatments was greater than sole cropping. The maximum land equivalent ratio (2.21 and 2.44) was obtained when T_1 (3 peas plants:1 lettuce plant) is applied within the first and second seasons respectively. Therefore, intercropping of pea and lettuce, especially at high legume density was appropriate. However, the LER of T_3(1 pea plant:1 lettuce plant) recorded the lowest value within the two seasons of study. The lack of response of land equivalent ratio under the lowest legume density. However, net benefit to the farmer was higher just in case of intercropping pea with lettuce as T_1(3 peas plants:1 lettuce plant), followed by pea intercropping with lettuce as T_4 (Side pea: side Lettuce), then by applying T_2 (2 Pea plants:1Lettuce plant) (Table.3). The LER of all intercropping treatments were greater than 1. This can be a sign of the resource use efficiency of pea/lettuce intercropping system. Also, indicating a higher combined yield was produced than for mono-cropped pea.

Aggressiveness

Aggressiveness is a value that shows how much the relative yield of one crop component is greater than that of another (McGilchrist 1965). Calculated "aggressiveness" proved that all secondary crop treatments were more dominant and were strong competitors than pea in all intercropping treatments (Table 3). Aggressivity index showed that pea intercropped with lettuce as T_3 (1 Pea plant: 1Lettuce plant) treatment gave the best value. However, Intercropping had sufficient economic benefits during this mixture.

Monetary advantage index (MAI)

Calculating monetary advantage index (MAI) is considered an indicator of the economic feasibility of cropping systems, results presented in Table3showed that, all treatments gave positive values of MAI because the LER values were greater than one. Indicated that the best MAI values of 33576.67 and 37195.67 were obtained from intercropping pea with lettuce by the ratio of 3Pea plants: 1 Lettuce plant (T_1) treatment in both seasons respectively, followed byT_4 (Side pea: side Lettuce) treatment (Table 3). While in the descending order is T1, T4, T2, and T3 These results are agreement therewith obtained by Hamd Alla *et al.*, 2014 who's revealed that economic benefit expressed with the higher MAI values in intercropping systems (Hamd Alla *et al.*, 2014).

Table 3. 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 2019-2020.

Treatment	Main Crop	Secondary Crop	Relative Yield Main Crop	Relative Yield Secondary Crop	LER	Aggressiveness for Main Crop	Aggressiveness for Secondary Crop	MAI
Season 1								
T_1 (3Pea :1Lettuce)	Pea	Lettuce	0.83	1.38	2.21	-1.1	1.1	33576.67
T_2 (2 Pea:1Lettuce)			0.62	1.33	1.95	-1.44	1.44	26705.23
T_3 (1 Pea:1Lettuce)			0.37	1.21	1.58	-1.69	1.69	15917.69
T_4 (Side pea:sideLettuce)			0.99	1.12	2.11	-0.26	0.26	30658.09
Season 2								
T_1 (3Pea :1Lettuce)	Pea	Lettuce	0.83	1.61	2.44	-1.56	1.56	37195.67
T_2 (2 Pea:1Lettuce)			0.62	1.54	2.16	-1.85	1.85	30216.92
T_3 (1 Pea:1Lettuce)			0.38	1.29	1.67	-1.83	1.83	17878.16
T_4 (Side pea:sideLettuce)			0.98	1.28	2.26	-0.58	0.58	33572.86

Conclusion

Intercropping systems can increase land-use efficiency, but it may also lead to a slight decrease in the yield of the main crop due to the competition for resources. From the results of the present study, it can be concluded that lettuce may be successfully intercropped with pea with a significant increase in the yield in all treatments. However, the yield of pea was significantly decreased in all intercropping systems except for side lettuce: side pea (T_4) treatment. Maximum economic benefit was obtained from intercropping lettuce with pea by the ratio of 3pea plants: 1 lettuce plant (T_1) treatment. The system was found to be stable when the high pea density of ratio of 3Pea plants: 1 lettuce plant (T_1) treatment was used. The extra yield of lettuce within the intercropping treatment also increased economic gross returns.

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Website:*www.aun.edu.eg/faculty_agriculture/journals_issues_form.php* ***E-mail: ajas@aun.edu.eg***

دراسة تأثير تحميل الخس مع البسلة علي النمو والمحصول والجودة الغذائية

شرين يعقوب عطا الله[١]، محمد حمام زين العابدين[□]، منال عبد الحميد محمود[□] وسمية حسنى احمد[□]

[١]قسم الخضر – كلية الزراعة – جامعة أسيوط
[٢]قسم علوم وتكنولوجيا الاغذية – كلية الزراعة – جامعة اسيوط

الملخص

اجريت هذة الدراسة بمزرعة التجارب البحثية – كلية الزراعة – جامعة اسيوط وذلك خلال موسيمين زراعيين 2017-2018، 2018-2019، وذلك لدراسة تأثير انظمة تحميل مختلفة لمحصولى الخس والبسلة وهى كالتالى: 3 نباتات بسلة:1 نبات خس،2 نبات بسلة:1 نبات خس،1 نبات بسلة:1 نبات خس، ريشة نبات بسلة: ريشة نباتات خس هذا بالاضافة الى معاملتى الكنترول (بسلة فقط، خس فقط) على النمو والمحصول وصفات الجودة، الى جانب الجدوى الاقتصادية.

اوضحت النتائج المتحصل عليها ان تحميل الخس مع البسلة كان اكثر فاعلية من زراعة البسلة بمفردها فى هذة الدراسة، حيث ادى الى زيادة معنوية فى محصول الخس مقارنة بزراعتة منفردا. وكانت الزيادة تتراوح ما بين 12.2-37.7% فى الموسم الاول، 27.7-60% فى الموسم الثانى على التوالى بينما ادت انظمة التحميل المختلفة الى نقص فى محصول البسلة فى كل المعاملات باستثناء معاملة ريشة بسلة: ريشة خس حيث اعطت محصول مماثل لمعاملة الكنترول، بينما تراوح النقص فى المعاملات الثلاثة الاولى ما بين 17-62.9%، 17.2-61.6% فى الموسم الاول والثانى على التوالى وذلك طبقا لنظام التحميل المستخدم. واوضحت النتائج المتحصل عليها ان تحميل الخس مع البسلة كان ذا جدوى على الرغم من نقص محصول البسلة فى الثلاث معاملات الاولى ولكن هذا النقص تم تعويضة بمحصول الخس الاضافى. وكانت اعلى كفاءة تمثيلية لاستغلال الارض تم الحصول عليها من تطبيق معاملة 3 نباتات بسلة: 1 نبات خس والتى ايضا اعطت اعلى عائد اقتصادى.