EFFECT OF INTERCROPPING ON THE PERFORMANCE OF SOME SUMMER VEGETABLE CROPS GROWN UNDER DIFFERENT ROW ARRANGEMENTS

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Abstract

This study was conducted in a private farm in Madaba region during 2007 summer growing season. The objectives of this study were to determine the potential and response of some summer vegetable crops to intercropping system and to define the best combinations which yield highest production. Four vegetable crops namely bush bean, okra, lettuce and squash were planted in six combinations. Each combination was planted under four different row arrangements (1:1, 1:2, 2:1, 2:2) in the open field. Okra and lettuce gave higher significant yields when they were planted with bean under all row arrangements, where they gave an average increase in yield of 45% and 66%, respectively, over their sole crops. Additionally, the yield of okra was affected by the associated crops (bean, lettuce and squash). The least significant yield of okra was obtained when it was intercropped with squash under 1:2 row arrangement (5.5 ton ha^{1}). However, the other row arrangements of okra as it was planted with squash were on the same level of significance when compared to okra sole crop (7.01 ton ha^{1}). On the other hand, bean gave the highest significant yields when it was intercropped with lettuce and squash under all row arrangements. However, when bean was intercropped with okra, significantly highest yield (16.66 ton ha^{1}) was obtained under 2:1 row arrangement as compared to okra yield sole crop (13.63 ton ha^{1}).
For squash, significantly highest yields were obtained when it was intercropped with bean under 2:1 and 2:2 row arrangements as compared with squash yield sole crop. Moreover, in the squash / okra combination, yields under row arrangements of 1:1 and 1:2 were significantly less than squash yield sole crop. However, the other combinations under different row arrangements were intermediate in yields. Regarding the efficiency of intercropping as it was judged by LER, the results showed that almost all the intercropping combinations with their row arrangements tested gave LER values more than one indicating the superiority of intercropping over sole cropping.

Key words: Intercropping, Vegetable Crops, LER

Vegetable crops failures are common under irrigated areas due to insect and disease infections or due to the prices that go up and down according to supply and demand. Therefore, it was recommended to practice intercropping, the agricultural practice of cultivating two or more crops simultaneously in the same piece of land. This cropping system might provide insurance against crop failure by reducing disease(Fininsa, C. and Yuen, J 2002, Sharaiha, R. et al., 1989) and insect incidence (Girma, H. et al., 2000, Gahukar, R. 1989)) or against unstable market prices by planting two or more crops under intercropping, and thus reducing the risk of unexpected changeable prices. It was shown by many researchers that intercropping of different vegetable crops provided important advantages as well as higher profitability than vegetables grown as sole crops (Willey, R. 1979; Sharaiha, R, and Haddad, N. 1985; Nursima, K. 2009). However, yield production of vegetables grown under intercropping depends on the component of the crops selected as well as row arrangements. Lewis, W. et al. (2003) showed that lettuce yields were reduced when concurrently intercropped with tomato, as compared with sole lettuce crop, while Sharaiha, R. and Gliessman, S. (1992) indicated that lettuce intercropped with faba bean under 2:1 and 2:2 row arrangements gave less production as compared to 1:1 row arrangement and lettuce sole crop. El-Shimi, I. and Amer, A. (2003) noted that okra planted with snap beans gave a reduction in okra yield as compared with okra sole crop. In addition, okra intercropped with peas under 2:1 and 1:2 row arrangements gave better yields than 1: 1, 2:2 and their sole crops (Sharaiha, R. and Hadidi, N. 2007). The results of a series of studies have shown that the overall yield of corn, bean and squash as they were grown in combination were greater than if they were grown separately in monocultures (Gliessman, S. 1988). In contrast, Stephen, J. and Michael, K. (1982) reported that squash yield was reduced significantly when it was grown in mixture with corn due to the shading

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effect created by corn crop. However, shading to a certain degree was found to be beneficial for certain crops such as potato bean and corn grown under row intercropping with a specific design of row arrangements (Sharaiha, R. et al., 2004). More work of this nature is needed and calling for more research due to the conflicting results obtained by different researchers. Therefore, the objective of this study was to determine which of the following vegetable crops: bean, lettuce, okra and squash grow best under different combinations and intercropping row arrangements that result a greatest yield and provide better land use efficiency, which could be useful to farmers in Jordan.

MATERIAL AND METHOD

Research project entitled by the effect of intercropping on the performance of some summer vegetable crops grown under different row arrangement was conducted during 2007 summer growing season in a private farm in Madaba region, which is situated on a latitude 31°59'N, longitude, 35°59'E and at an altitude around 800m above sea level. The average maximum and minimum temperatures during growing season were 17°C - 32°C and 6°C - 18°C, respectively, while average of relative humidity ranged between 36% and 59%. Bean (*Phaseolus vulgaris*, var. Bronco), okra (*Ablmoschus esculentus*, var. local), lettuce (*Lactuca sativa* var. local), and squash (*Cucurbita maxima* var. XPh 1517) were planted with each other that resulted in six different combinations (bean/okra; bean/lettuce; bean/squash; okra/lettuce; okra/squash; squash/lettuce). Each combination was planted under different row arrangements namely 1:1, 1:2, 2:1, 2:2, in the opened field including their sole cropping. Planting date for bean, okra, and squash were on March 15th, while lettuce was transplanted on April 4th in their reserved rows as it was designed for them. Every treatment plot consisted of six rows 75cm apart and 4 meters long. Spacing between plants within row were 25cm, 20cm, 35cm and 55cm for bean, lettuce, okra and squash, respectively. Gap filling or thinning was carried out subsequently to achieve an optimum plant stand. Compost poultry manure was applied one week before planting at the rate of 18 Mt.ha-¹. Weeds were kept under control manually. Drip irrigation was used. A split plot in a randomized complete block design was used with intercropping combination as the main plot treatments, and row arrangements as sub plot treatments. Three replications were used. At maturity, in 1:1 and 2:2 row arrangements, the two outer rows were left as borders and the middle three meters of the central four rows were harvested, while in 2:1 and 1:2 row combinations, three rows were left as borders and the middle thee meters of the central rows were harvested.

The harvesting periods were as follows:

a- Lettuce from May 17th to June 1st

b- Bean was picked for fresh green pods from June10th to July 5thth

c- Okra was picked from July 10th to August 8th

d- Squash was picked from June 30th to July 29th.

Land equivalent ratio (LER) was evaluated by considering the yield of each crop. Land equivalent ratio is defined as a relative land area under sole cropping that is required to produce the yield achieved in intercropping. Land equivalent ratio was calculated for the combined intercrop yields and for the intercrop yield of each crop, as described by Willey, R. (1979), who expressed the intercrop yield on a relative basis to a sole crop yield (i.e. were LER = 1.00).

RESULTS AND DISCUSSIONS

Bean Yield

Intercropping of bean with okra, lettuce, and squash seems to have beneficial effect on bean yields especially when lettuce and squash were the associated crops (*tab.1*). Increases in intercropped bean yields over bean sole crop were ranged between 16% and 60% as bean was intercropped with lettuce, while as bean was intercropped with squash were ranged between 15% and 48%. The highest significant bean yield was obtained when it was planted with lettuce under 2:1 and 2:2 row arrangements while with squash it was under 2:1 and 1:1 row arrangements. The increases in yields of bean as it was intercropped with lettuce could be due to the rapid growth and earlier harvesting of lettuce that gave less competition to the available resources as compared to bean sole crop. However, in case of bean intercropped with squash, the increases in bean yields could be explained due to the creeping squash stem and bean bushy growth habit stem. This situation creates wider spacing between rows of bean as they grow under different intercropping row arrangements. Thus, intercropped bean plants with different row arrangements are more exposed to light as compared to bean sole crop. Similar results were obtained by Gliessman, S. (1988) in his work on corn, bean and squash intercropping. On the other hand, bean intercropped with okra was not affected significantly compared to its sole crop, with one exception of bean grown with okra under 2:1 row arrangement, where it gave significantly higher yield than either its sole crop or as it was grown with okra under 1:1 and 1:2 row arrangement. The differences in yield could be attributed to the distribution of bean roots that might affect the root / shoot ratio and consequently affected the efficiency of using moisture and nutrient recourses

according to the type of row arrangement. However, in the present study no measurements were made on root distribution or in moisture and nutrients uptake, therefore, it is only possible to speculate about this point.

Table 1

Yield (Ton ha^{-1}) of bean intercropped with okra, lettuce and squash under different row arrangements during 2007 growing summer season

Intercropping combination	Row arrangement			
	1:1	1:2	2:1	2:2
Bean / Okra	13.84 de	13.25 de	16.66 b	14.81 b-d
Bean / Lettuce	16.59 b	15.77 bc	20.00 a	21.77 a
Bean / Squash	20.22 a	16.15 bc	20.10 a	15.62 bc

Bean sole crop = 13.63 de

Means followed by the same letter do not differ significantly at 5% level according to Duncan's Multiple Range Test (DMRT) Lettuce Yield

Table 2 showed that the effect of the associated crops (okra, bean and squash) on lettuce yield is more than the effect of row arrangements, since no significant differences were obtained among the treatments of row arrangements in each combination that include lettuce plants. However, the results from this study showed that lettuce grown with okra, bean and squash gave different responses in yield according to the associated crop. The highest significant yield was obtained when lettuce was grown with bush bean under all row arrangements used, where it gave an increase in yield ranged from 58% to 79% over the yield of lettuce sole crop. However, since lettuce was transplanted after bean by 20 days, therefore, it was expected that a legume crop such as bean, which is capable of fixing atmospheric nitrogen, would have a beneficial effect on lettuce crop as a non-legume crop, especially when chemical fertilizer was not applied. This fact has been pointed out by many researchers such as Francis, C, and Sander, J. (1978), Willey, R. (1979) and Sharaiha, R. & Kluson, R. (1994). On the other hand, lettuce grown with okra gave variable yields according to the intercropping row arrangement. Although the differences among the four intercropping treatments and sole crop treatment were not statistically significant, the trend indicates the following results: 1- a reduction in yield of 13% as compared to its sole crop was obtained under 2:2 row arrangement, 2- approximately an equal yield to its sole crop such as in 1:1 and 1:2 row arrangements 3- an increase in yield of 16% compared to its sole crop such as in 2:1 row arrangement (*tab. 2)*. Differences in yield could be attributed to the different microenvironment created by each row arrangement. 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, fababean and pea on weed biomass, diversity and on yields. Moreover, when lettuce was intercropped with squash, it seems that squash have a beneficial effect on lettuce yield under all row arrangements (*tab. 2*). Although the differences were not statistically significant, the trend indicates the superiority of intercropping system over sole cropping system. This could be explained by the contrasting nature of the two associated crops, whereas lettuce have an erect stem and squash with its creeping stem that sprawl and extend along the ground around the lettuce plants. Thus, squash plant might acts as a natural mulch reducing soil temperature and helping to hold moisture in the soil, where it might be used by lettuce and not be lost through soil evaporation as it might to be in case of lettuce sole crop.

Table 2

Yield (Ton ha^{-1}) of lettuce intercropped with okra, bean and squash under different row arrangements during 2007 growing summer season

Intercropping combination	Row arrangement			
	1:1	1:2	2:1	2:2
Lettuce / Okra	13.56 d	14.16 d	16.56 bd	12.36 d
Lettuce / Bean	22.74ab	25.58 a	22.50 ac	24.18 a
Lettuce / squash	18.22a-d	17.70a-d	17.78 a-d	15.30cd

Lettuce sole crop = 14.28 d

Means followed by the same letter do not differ significantly at 5% level according to Duncan's Multiple Range Test (DMRT)

Okra Yield

Results in table (3) showed that bean have more beneficial effect on okra yields than either lettuce or squash, where okra yield gave a significant average increase of 45% (sig) over okra yield sole crop. This was expected from a legume crop such as bean that fixes atmospheric nitrogen in the soil that might be beneficial to okra crop. Similar results were obtained by other researchers (Francis, C, and Sander, J. (1978), Willey, R. (1979) and Sharaiha, R. & Kluson, R. (1994). Further more, when okra was planted with bean under 1:2 row arrangements gave the highest significant yield (11.76 ton ha^{-1}) as compared with okra yield sole crop (7,01 ha^{-1}) and with okra planted with either lettuce or squash under all row arrangements.

Although yield of okra in 1:2 okra / squash intercropping row arrangement was significantly less than okra yield sole crop, the other row arrangements were in the same level of significance. This indicating that okra did not benefit from squash and that might be due to the competition between these two crops for the available resources. Similar results were obtained by Akintoye, H. et al. (2011) in their work on okra / pumpkin intercropping.

However, okra yields in combination with lettuce under 1:1 and 2:1 row arrangements (8.32 ton $ha^{-1}$and 8.28 ton ha^{-1}) were significantly higher than the yield of okra sole crop (7.01 ton ha^{-1}) while the other row arrangements did not different significantly. Differences in okra yield could be due to different micro environment created by different row arrangements. Therefore, the associated crops and the row arrangements play an important role on the productivity of okra yield, since each combination under certain type of row arrangement create a different micro environment that affect okra yield production. These findings are in agreement with Ahmed, B. et.al. (2004) in their work on effect of cropping arrangement on the growth and yield of okra.

Table 3

Yield (Ton ha^{-1}) of okra intercropped with bean, lettuce and squash under different row arrangements during 2007 growing summer season

Intercropping combination	Row arrangement			
	1:1	1:2	2:1	2:2
Okra / Bean	9.12 bc	11.76 a	9.60 b	10.10 b
Okra / Lettuce	8.32 c	8.11 cd	8.28 c	8.07 cd
Okra / Squash	6,60 de	5.50 e	6.92 de	7..06 d

Okra sole crop = 7.01 d

Means followed by the same letter do not differ significantly at 5% level according to Duncan's Multiple Range Test (DMRT)

Squash yield

Table 4, showed that squash intercropped with bean, lettuce and okra gave variations in squash yields according to the associated crop and their row arrangements. However, the highest significant squash yield was obtained when squash was planted with bean under 1:2 row arrangement, where an increase in yield of 22% was obtained over the yield of squash sole crop, whereas the yield of squash in the other row arrangements with bean were not statistically different, but the trend still indicates the superiority of intercropping system. This could be explained by the efficient use of available resources per unit area for different crops, (Willey, R. et al. 1977, Sharaiha, R. and Hattar, B. 1993, Muoneke, C. and Ndukwe, O 2005). Moreover, when squash was intercropped with lettuce under different row arrangements (1:1, 1:2, 2:1, 2:2), none of these treatments affected squash yield. This might indicate that there is no agronomical interaction between these two crops due to the wider spaces between the rows of lettuce that make squash react as a sole crop. According to squash / okra intercropping, the results in table 4, showed that squash gave significant higher and lower yields as compared to squash yield sole crop. The highest significant yields were obtained under 2:1 and 2:2 squash okra intercropping row arrangements, where the yield of squash in both treatments was more than the yield of squash sole crop by around 17%. On the other hand, the lowest yields of squash were obtained under 1:1 and 1:2 squash / okra intercropping row arrangements, where it gave a reduction in yield by around 13% for both treatments. The highest and lowest yield production of squash could be due to the shading effect, once shading is at minimum grade such as in 2:1 and 2:2 squash /okra intercropping row arrangements it might give the squash an optimum shading condition for yield production. These results are in agreement with the findings of willey, R. (1979) and Sharaiha, R. and Hadidi, N. (2007) whom they found that certain degree of shading could be beneficial for certain crops. However, according to squash as it was planted in a single row between two rows of okra plants (1:2) and as it was planted in alternate rows with okra (1:1) the shading according to their row arrangements is at highest grade as compared with the case mentioned above and that might affect

negatively squash yield production. Similar results were found by Stephen J. et al. (1982) in their study on plant growth, flowering, phonologies and yield of corn, bean and squash grown in pure stand and mixtures, they explained that squash shaded by corn produce fewer flowers which resulted in reduction of squash yield. Therefore, the design of the rows arranged in squash / okra intercropping system could be one of the factors that determines the success or the failure of this cropping pattern.

Table 4

Yield (Ton ha^{-1}) of squash intercropped with bean, lettuce and okra under different row arrangements during 2007 growing summer season

Intercropping combination	Row arrangement			
	1:1	1:2	2:1	2:2
Squash : Bean	11.12 b	13.44 a	11.46 b	11.52 b
Squash : Lettuce	10.94 b	11.82 b	10.81 b	11.25 b
Squash : Okra	9.65 c	9.71 c	12.86 a	12.92 a

Squash = 11.04 b. Means followed by the same letter do not differ significantly at 5% level according to Duncan's Multiple Range Test (DMRT)

Land Equivalent Ratio (LER)

The efficiency of intercropping in this study was evaluated by determining the resultant LER. LER is defined as the relative land area under sole cropping that is required to produce the yield achieved in the intercropping. When the values of (LER) are greater than one under intercropping system, this result indicates the efficient of land use as compared to sole cropping. Table 5 reports the calculated LER for all the intercrop combinations that are planted under different row arrangements. Thus, it shows that almost all the intercrop combinations of bean / okra; bean / lettuce; bean / squash; okra / lettuce; okra / squash, and squash / lettuce gave LER values of more than one, with very few exceptions. It is also clear that the efficiency of intercropping was seriously affected by crop combination as well as by row arrangements. This is logical since each combination of two crops and their row arrangement allowed for special local microenvironment for each plant, changing the competition for light, moisture and nutrient (Willey, R. 1979. Francis, C and Sanders, J. 1978. Sharaiha, etal. 2004).

Comparison of LER values obtained by bean as it was intercropped with each of okra, lettuce and squash under different row arrangements, (*tab.5)* indicated that the highest LER values were found when bean was intercropped with lettuce under all row arrangements and it ranged between 1.41 and 1.65 with more contribution from lettuce, except in 2:1 bean / lettuce where the contribution from bean was more than lettuce. This might indicates that the way of arranging the rows of bean and lettuce that grown under intercropping system could play an important role in which crop contribute more in row intercropping system. This fact was pointed out by Hugar H. and Palled Y. (2008) in their work on maize-vegetable intercropping systems.

Moreover, When the intercropping of bean and okra under all row arrangements used are considered, the values of LER was ranged between 1.16 and 1.37 with more contribution from okra plants under all row arrangements because okra plants gave a relative LER values of 15%, 24%, 23% and 22% under 1:1, 1:2, 2:1 and 2:2, respectively, which are more than what was expected by okra sole crop planted in half, 1/3, 2/3 and half of the land, respectively. On the other hand, the contribution of the bean plants was 1%, 4%, and -1% and 4% under similar row arrangements, respectively. The differences in values of relative LER between okra and bean grown in association under different row arrangements were due to different local micro-environment created by each crop grown under different row arrangement.

When bean was intercropped with squash, the values of total LER varied between 1.09 and 1.39, with more contribution from bean under all row arrangements. The greatest LER value was found when bean was intercropped with squash under 2:1 row arrangement. This could be explained that bean was more efficient in using the available resources than squash under such conditions of local microenvironment.

A comparison between okra plants as they were intercropped with squash and lettuce under all row arrangements tested (tab.5.); indicate that the total LER values were higher when okra was planted with lettuce than with squash under all row arrangements, except in 2:2 row arrangement where okra planted with squash obtained a LER value higher than okra with squash. However, the LER values under this combination were more than one in all row arrangements except the two treatments of 1okra:1squash and 2 okra:1squash row arrangements, where their values of LER were 0.90 and 0.95, respectively. These two values are

less than what was expected by 10% and 5%, respectively. It seems that the differences in LER values between okra / lettuce and okra / squash depend on the crop that associated okra plant and on their row arrangements, because each combination of crops under different row arrangements have a different response to the available resources (light, nutrient and moisture). Similar results were obtained were obtained by Hugar H. and Palled Y. (2008) in their work on maize-vegetable intercropping systems.

Furthermore, when squash and lettuce were grown under intercropping with different row arrangements (tab.5.), the total LER values obtained ranged between 1.04 and 1.19 with more contribution from lettuce under all row arrangements. The higher contribution of lettuce was due to the higher relative LER values obtained by lettuce as compared to the values of relative LER obtained by squash under all row arrangements. However, the differences in values of relative LER were reflected from the differences between their yields obtained under intercropping and sole cropping.

Table 5

Relative land equivalent ratio (LER) and total LER of bean, lettuce, okra and squash grown in association under different row arrangements during 2007 growing summer season

Treatments	Relative LER		Total LER
1 row Bean : 1 row okra	0.51	0.65	1.16
1 row Bean : 1 row lettuce	0.61	0.80	1.41
1 row Bean : 1 row Squash	0.74	0.50	1.24
1 row Bean : 2 rows okra	0.32	0.91	1.23
1 row Bean : 2 rows lettuce	0.39	1.05	1.44
1 row Bean : 2 rows Squash	0.39	0.69	1.08
2 rows Bean :1 row okra	0.81	0.56	1.37
2 rows Bean :1 row lettuce	0.98	0.60	1.58
2 rows Bean :1 row Squash	0.98	0.41	1.39
2 rows Bean :2 rows okra	0.54	0.72	1.26
2 rows Bean :2 rows lettuce	0.80	0.85	1.65
2 rows Bean :2 rows Squash	0.57	0.52	1.09
1 row okra :1 row lettuce	0.59	0.47	1.06
1 row okra :1 row squash	0.47	0.43	0.90
1 row okra :2 rows lettuce	0.39	0.77	1.16
1 row okra :2 rows squash	0.26	0.78	1.04
2 rows okra :1 row lettuce	0.79	0.33	1.12
2 rows okra :1 row squash	0.66	0,29	0.95
2 rows okra :2 rows lettuce	0.58	0.43	1.01
2 rows okra :2 rows squash	0.50	0.58	1.08
1 row squash :1 row lettuce	0.50	0.64	1.14
1 row squash :2 rows lettuce	0.36	0.83	1.19
2 rows squash :1 row lettuce	0.65	0.41	1.06
2 rows squash :2 row lettuce	0.51	0.54	1.04

Bean Sole crop = 1
Okra Sole crop = 1
Lettuce Sole crop = 1
Squash Sole crop = 1

CONCLUSIONS

The study showed differences in yield between sole and intercropping under different row arrangements.

Okra, squash and lettuce crops, gave higher yields and LER values when they are intercropped with bean specially under 1:2 row arrangement.

Lettuce and squash seem to be more beneficial to bean than okra under all row arrangements tested.

When squash is intercropped with okra, row arrangements should be taken in consideration because it might influence the yield of squash.

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