ENVIRONMENTAL IMPACT ON YIELD OF PEA AND OKRA GROWN UNDER INTERCROPPING

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An experiment was conducted at the Faculty of Agriculture Research Station, University of Mu`tah in Rabbah, South Jordan, during summer growing season 2002. The objective was to study the effect of air and soil temperature, light intensity, soil moisture storage (SMS), evapotranspiration (ET), and water use efficiency (WUE) on the yields of okra and pea as they were grown under sole cropping and intercropping systems with four row arrangements(1:1, 1:2, 2: 1, 2: 2).

A randomized complete block design with three replications was used; each plot consisted of eight rows, 60 cm apart and 4 m long. Spacing between plants within row was 20 cm and 10 cm for okra and peas respectively.

Okra and pea gave highest yields when grown in 1: 2 and 2: 1 intercropping row arrangements. Sole yields of pea and okra were 7.701 and 10.186 ton ha, $^{-1}$ respectively. The increases in pea yields were 3.51 and 3.32 ton ha $^{-1}$at 1:2 and 2:1, while those of okra yields were 5.94 and 6.52 ton ha, $^{-1}$ respectively, over their sole crops.

The increases in pea yields could be related to reductions in air heat unit (by 15.3 and 9.3), soil heat unit (by 123 and 133.3), ET (by 58 and 126 mm), in addition to increases of WUE (by 0.141 and 0.144 ton/ha/cm) as pea was grown with okra under 1: 2 and 2: 1 row arrangements, respectively, but no differences in light intensity (with the exception of 1:2 pea / okra intercropping) and SMS. On the other hand, the increases in okra yields were associated with increases in air heat unit (by 29 and 16.3), soil heat unit (by 53.7 and 55.1), light intensity (by 305 and 150 µmol.m^{-2}s^{-1}) and WUE (by 0.261 and 0.242 ton/ha/cm) under the same row arrangements, respectively. However, the other microclimatic factors were not associated with okra yield. The land equivalent ratio (LER) values under all intercropping treatments were greater than one, which gave an indication of intercropping superiority over sole cropping.

The main conclusion and recommendation which could be drawn from this research are the followings:

1. The best intercropping row arrangement that gave higher yield for pea and okra is 1:2 and 2:1.

2. A major cause of yield advantage of pea / okra intercropping is the better use of growth resources (light, temperature and water) as a result of complementary effects between the crops involved.

3. Temporal complementarily produced more advantage than spatial complementarily, but this needs further investigation.

***Keywords**: pea, okra, intercropping, row arrangement, yield.*

Research on intercropping system (planting two or more crops on the same piece of land at the same time or during part of the life cycle of each) is becoming very common in Jordan as well as in other countries. There are several reasons encouraging small farmers to adopt intercropping system, which include stability of yield; a better variety of returns from land and labor; increased efficiency of scarce resources utilization; and reduce the risk of dependence upon a sole crop that is susceptible to environmental and economic fluctuations. It was indicated that light use efficiency could be an important factor for the yield advantages under intercropping system such as millet with groundnut (Radke and Hagstrom, 1976) and potato with corn intercropping (Sharaiha and Battikhi, 2002). Elsayed and Kandeel (2003) showed that low density of trees, (Casurina glauca and Eucalyptus camaldulensis), modify the microclimate for okra, cowpeas and squash and offers a beneficial effect on their physiological processes. Kuruppuarachchi, (1990) found that the benefit of shading on intercropped potato yields was variable and this variability might be related to the degree of shading. Batugal et al. (1990) reported that intercropping maize with potato could be beneficial in providing partial shade for potato and reduce both air and soil temperatures. Sharaiha and Kluson (1994) reported that both soil and air temperatures required for faba bean nitrogen fixation were significantly higher when it was planted with pea as compared with faba bean sole crop. Al-Qahwaji, (1994) pointed out that evapotranspiration for potato and faba bean under intercropping was less than that of sole cropping, while water use efficiency was significantly higher under intercropping than under sole cropping. Midmore, (1990) found that the higher yields of corn intercropped with potato were due to the higher amount of soil moisture storage caused by a decrease in demand of water after potato maturity. Natrajan and Willey (1980) indicated that intercropping might give relative advantages under conditions of moisture stress but little or none under no stress conditions. Yet, exactly the opposite results were found by Lakhani (1976), cited by Willey (1979), when fodder radish / sunflower were considered. Sharaiha and Battikhi, (2002) showed that the effect of temperature, light interception, soil moisture storage, evapotranspiration, and water use efficiency under intercropping system were varied according to crop combination and row arrangements within a combination. Since the microenvironmental factors depends on intercropping combinations and row arrangements, more work of this nature is needed to provide more information in order to improve the intercropping system. Therefore, the objective of this experiment is to study the effect of okra / pea intercropping on the following ecological parameters: -Air and soil temperatures; light interception; soil moisture storage; evapotranspiration; water use efficiency; and consequently on the yield of okra and pea.

MATERIALS AND METHODS

A field experiment was conducted in 2002, summer growing season at the University of Mutah, Faculty of Agriculture Field Station, in Rabbah, (31.2º N, 35.5º E, altitude 920 meter above the sea level, 120 km. South of Amman). The soil texture is clay loam, the climate is semi-arid with mean annual precipitation of 326 mm and mean annual temperature of 16.2ºC. Okra (variety C-Spineless) and pea (variety Red Thiram) were planted during summer growing season 2002 (March 31) under intercropping system with four row arrangements, (1:1; 1:2; 2:1; and 2:2;) in addition to their sole crops. Composed poultry manure was applied before planting at the rate of 15Mt. ha^{-1}. A randomized complete block design with three replications was used; each plot consisted of eight rows, 60 cm apart and 4 meters long. Spacing between plants within row was 20 cm and 10 cm for okra and pea, respectively. Weeds were kept under control manually. Surface lateral pipes of 16mm diameter were installed on every planting row in order to deliver water to plants. In line, drippers with 40 cm spacing and 4 liters per hour per dripper discharge rate were used for irrigation. The amount of water added was recorded by water meter. Soil moisture measurements were taken at 7.5, 22.5, 45 and 75 cm soil depth using neutron probe. In addition, gravimetric method was used to support neutron probe readings for the first two layers. Two access tubes of 90 cm long and two inches diameter were installed within the row between two adjacent okra and pea plants under intercropping treatments, while one access tube was installed for each sole crop. Calibration for different soil layers was correlated with soil moisture counts of neutron probe with gravimetric soil moisture samples. Linear regression equation for calibration of neutron probe for the third layer was Pv%= 38.30 CR – 15.23, and that for the fourth layer was Pv% =29.88CR – 15.23, where Pv% is a volumetric moisture content and CR (count ratio) is a neutron probe reading in the field. Crop evapotranspiration (ET) and soil moisture storage (SMS) were calculated by using the following equations: - -ET= R+I+Dsi –DP. Where R: is the amount of rainfall and it was equal to zero. I: is the amount of irrigation, Dsi: is the initial soil moisture content and DP: is deep percolation and it was equal to zero. -SMS= Σ [Increase in soil moisture (+Δs)] where Δs is the difference between two neutron probe readings for the soil moisture storage taken after irrigation by 16 hours and before each irrigation. While water use efficiency (WUE) was calculated by dividing yield over ET. Daily light and temperature (air & soil) measurements (taken between 11 AM and 1 PM) started 24 days after plant emergence using porometer and thermometer, respectively. However, soil and air temperatures were recorded as heat unit, using the 50 – 80F method (Battikhi and Ghawi, 1987). The heat unit method should indicate which of the treatments provided best temperature for plant growth. Light measurement was taken at lower, middle and the upper part of the stem (averages were calculated). Harvesting date started on May 16 and ended on July 31 for both crops. Yield for both crops were obtained from the middle three meters of the central four rows for 2:2 and 1:1 row combinations and from the middle of the central three rows, for 1:2 and 2:1 row combinations. The land equivalent ratio (LER) was calculated for the combined intercropped yields and for the intercrop yield of each crop, as described by Willey (1979), who expressed the intercrop yield on a relative basis to a sole crop yield (i.e. where LER = 1). Analysis of variance for the micro- environment values and yield data were determined. The Duncan's Multiple Range Test (DMRT) was then employed for mean separation.

RESULTS AND DISCUSSION

Effect of Intercropping Pea / Okra on Air and Soil Heat Units VS Pea Yield

Average air and soil heat units for pea as it was grown under sole cropping and intercropping are presented in table 1A. It is clear that the variations in the values of soil heat unit under pea sole crop and pea intercropped with okra are more pronounced than those of the air heat unit, where a reduction of soil heat unit under pea intercropping was ranged between 60-133.3 as compared to pea sole cropping, while for air heat unit the reduction was ranged between 2.9-15.3. Batugal et. al (1990) explained the reduction in soil temperature to be due to radiation reflection, shading effect of the taller crop and water conserving properties under intercropping system. However, in the present study, the water conservation has not been clearly demonstrated. Moreover, a significant reduction of air and soil heat unit was obtained when pea was planted with okra under 1: 2 and 2: 1 row arrangements as compared to pea sole crop. Where soil heat unit gave a decrease of 133.3 and 123.0, respectively. While air heat unit gave a decrease of 15.3 and 9.3, respectively, compared to its sole crop. This could be explained by the shading development effect caused by okra plants. Moreover, the significant higher yields of pea (Table3) were obtained under the same treatments (1:2 and 2:1), where the maximum reduction of soil and air heat unit were recorded. Therefore, the shading development gave optimum values of soil and heat unit that affected significantly yield of pea especially under hot dry summer conditions. This agrees with the findings of Sharaiha and Battikhi (2002) on their work on potato / corn intercropping and with Batugal et al (1990) on their work on potato / maize intercropping.

Effect of Intercropping Pea / Okra on Light interception VS Pea Yield

Intercropping pea with okra under different row arrangements (1:1, 1:2, 2:1, and 2:2) resulted in a reduction of light interception as compared with pea sole crop (Table 1A). However, significant maximum reduction was obtained under 1:2 pea / okra row arrangement, where it gave a decrease in light interception of 110.6 µ mol $m^{-2}s^{-1}$ as compared to the value obtained under pea sole crop. This could be attributed to the shading effect of okra plants on pea, since pea was planted between double rows of okra in each side. On the other hand, the highest significant yield of pea was obtained under the lowest value of light interception (1:2 pea / okra intercropping) where it gave an increase in yield of 45.6% over the yield of pea sole crop (Table3). However, the other intercropping treatments showed no significant differences in average light interception compared to pea sole crop, although yield of pea grown with okra in 2:1 row arrangement gave significant higher yield over its sole crop. Therefore, other factors might play an important role that affected positively the yield of pea as it was intercropped with okra in 2:1 row arrangement, such as evapotranspiration, water use efficiency (Table 2A) air and soil heat unit (Table 1A) in addition to the canopy development.

This fact has been pointed out by Sharaiha and Haddad (1985) in their work on potential of row intercropping of cabbage, broad bean and corn, and by Batugal et al. (1990) in their work on intercropping potato with maize in low land Philippines. However, the differences in yield of pea grown with okra under different row arrangements were not significant (Table3). This could be an indication that light interception for pea under intercropping row combinations were within range. Similar results were obtained by Harris (1990) in his study on "Crop radiation use: A justification for intercropping."

Effect of Intercropping Pea / Okra on Soil Moisture Storage (SMS) Evapo-transpiration (ET) and Water Use Efficiency (WUE) VS Pea Yield

There is no significant effect on SMS from intercropping pea with okra as compared with pea sole crop (Table 2A). These results are contradicted to what it is expected, specially when pea was intercropped with okra under 1:2 and 2:1 row arrangement where the values of soil heat unit, air heat unit (Table 1A) and ET (Table 2A) were lower than under pea sole crop. Therefore, this could be attributed to the water extraction of pea which might use the water from the upper part of root zone only and that is due to its shallow fibrous root system, while okra might have extracted water from the whole root zone, knowing that okra plants have deeper tap root system with wider root branches specially in the first 45cm (Shanan 1970). Thus competition for water especially at the upper part of the root zone might exist, leading to maintain the level of SMS under intercropped pea un reduced. These results agree with the findings of Trenbath (1976) and contradict the findings of Jeiming and Midmore (1990) and Midmore (1988), obviously due to different experimental conditions, where they used plastic mulch in the first experiment and irrigation was not applied in the second experiment. Moreover, the value of SMS obtained by pea planted with okra did not contribute in the increase of pea yield (Table3) as long as irrigation was practiced.

Furthermore, the ET values obtained by intercropped pea were generally lower than the values obtained by pea sole crop (Table2A). However, the lowest significant value of ET was obtained under 2:1 pea / okra intercropping row arrangement as compared with pea sole crop. This could be attributed to the effect of shading caused by okra plants. Similar results were obtained by Rao and Willey (1978) and Sharaiha and Battikhi (2002). On the other hand, pea under this treatment gave significantly higher yield as compared to its sole crop (Table3). Moreover, in the case of I: 2 pea okra intercropping row arrangement, the highest significant yield of pea was obtained, although the value of ET was not significantly different than the value of ET obtained by pea sole crop (Table 2A). This might indicate that ET was not the only factor affected the higher yield production of pea. There are other factors that might play an important role such as air heat unit, soil heat unit and light interception (Table 1A), where they were lower under 1:2 pea /okra row arrangement than pea sole crop. Radke and Hagstrom (1976) explained the higher yield production due to higher dry matter obtained by sheltered crops, where their transpiration to evaporation ratio is higher than un sheltered crops. Aside from the reduction of ET under pea / okra intercropping, WUE was improved significantly (Table 2A). The highest significant values of WUE obtained by pea as it was intercropped with okra under 1:2 and 2:1 row arrangements were due to the highest significant yields of pea as compared to its sole crop (Table3), since WUE was calculated by dividing yield over ET. It is believed that the higher yield of pea obtained under intercropping system was due to the interactions among different certain factors.

Effect of Intercropping Okra / Pea on Air and Soil Heat Units VS Okra Yield

When okra was planted with pea under 1:1, 1:2, 2:1 and 2:2 row arrangements, the soil and air heat unit values were higher than the values obtained by okra sole crop (Table 1B). However, among the above mentioned treatments, the last three treatments gave significant higher values of both soil and air heat units as compared to the values obtained by okra sole crop. This could be attributed to wider spacing between rows, where the incident radiation could penetrate through the intercropped okra plants to the soil surface. While okra planted as sole crop has a dense canopy and therefore less incident radiation passes through all the leaves along okra stem. This might explain the higher values of both soil and air heat units obtained under okra intercropping as compared to okra sole cropping. When a comparison between the two cropping systems (intercropping and sole cropping) regarding both air and soil heat units (Table 1B) in relation to okra yield (Table 3), two hypotheses can be drawn. The first, when air and soil heat units were significantly increased under intercropped okra as compared with okra sole cropping (such as in 1:2, 2:1 and 2:2 okra / pea intercropping row arrangements), the highest significant yields were obtained, where an increase in yield of 64%, 58.3% and 47.5%, respectively, over the yield of okra sole cropping. The second, when soil and air heat unit values under intercropped okra plants were not statistically different with the values obtained by okra sole cropping (such as in 1:1 okra / pea row arrangement), in this case the okra yield under intercropping and sole cropping were also not statistically different. Similar results were obtained by Sharaiha and Battikhi (2002), in their work on corn / potato intercropping. Moreover, there is another factor which might affected okra yield production positively, namely the associated pea crop that is capable of fixing atmospheric nitrogen will have a beneficial effect on okra which is non-legume crop. This fact has been indicated in many reports. (Francis and Sanders 1978, Ray and Mc Fadden 1991, Sharaiha and Kluson 1994)

Effect of Intercropping Okra / Pea on Light interception VS Okra Yield

Table 1A, shows that okra planted in association with pea under 1:1, 1:2, 2:1 and 2:2 row arrangements intercepted more light than okra sole crop. However, significant higher values of light interception were obtained when okra was planted with pea under 1:2, 2:1 and 2:2, where it gave an increase of 305 $\mu mol.m^{-2}s^{-1}$, 150 $\mu mol.m^{-2}s^{-1}$ and 223 $\mu mol.m^{-2}s^{-1}$ respectively, over the light interception value obtained by okra sole crop. The higher values of light interception obtained by okra intercropped with pea were due to wider spacing between rows. On the other hand, the highest significant values of light interception obtained by okra as it was planted with pea gave the highest significant okra yields. Similar results were obtained by Sharaiha and Haddad (1985) Batugal et. al (1990) and Sharaiha and Battikhi (2002). Moreover, Trenbath (1976) indicated that a plant with a usually long shoot, such as okra, in a dense sole crop would experience an especially unfavorable light regime and lead to a poor root shoot ratio due to a scarce supply of photosynthate. Therefore, the relatively small root of okra under sole cropping could be less efficient in using soil resources (moisture and nutrients) as compared to the roots of intercropped okra which might have better distribution and eventually better use of resources.

Table 1

Effect of intercropping pea and okra on light interception, air heat unit and soil heat unit during summer growing season of 2002

A: Pea crop

Row arrangements	Light interception $\mu mol.m^{-2}s^{-1}$	Air heat unit	Soil heat unit
1 row pea/ 1 row okra	1128.3 ab	1980 ab	1306 ab
1 row pea/ 2 rows okra	1066.9 b	1969.2 c	1243 b
2 rows pea/ 1 row okra	1o99.8 ab	1975.2 b	1232.7 b
2 rows pea/ 2 rows okra	1098.1 ab	1981.6 a	1299.2 ab
Pea Sole crop	1177.5 a	1984.5 a	1366 a

Values without common letters are significantly different using DMRT at 0.05 level
Air and soil heat units are analyzed separately – soil heat unit at 5cm depth
Heat unit or daily growth is measured by using the 50-86°F

B: Okra crop

Row arrangements	Light interception $\mu mol.m^{-2}s^{-1}$	Air heat unit	Soil heat unit
1row okra / 1 row pea	901.6 c	2020 bc	1245.9 ab
1 row okra / 2 rows pea	1185 a	2043 a	1272.7 a
2 rows okra / 1 row pea	1o3o b	2030.3 ab	1274.1 a
2 rows okra / 2 rows pea	1103 ab	2040.1 a	1276.8 a
Okra Sole crop	880 c	2014 c	1219 b

Effect of Intercropping Okra / Pea on Soil Moisture Storage (SMS) Evapo-transpiration (ET) and Water Use Efficiency (WUE) VS Okra Yield

Soil moisture storage and okra water consumptive use (ET) values for okra intercropped with pea were not statistically different than the values obtained by okra sole crop (Table 2B). This fact was not expected due to the higher values of soil and air heat units obtained by okra intercropping (Table 1B). It seems that as long as irrigation was applied the effect of soil and air heat units on soil moisture storage and evapotranspiration were reduced. Similar results were obtained by Sharaiha and Battikhi (2002) in their study on corn / potato intercropping. However, the higher yields obtained by okra as it was planted with pea under 1:2, 2:1 and 2:2 were related to other factors such as light interception, soil and air heat units (Table 1B), in addition to what was expected from a legume pea crop that fix atmospheric nitrogen in the soil that might be beneficial to none legume crop such as okra (Sharaiha and Kluson, 1994. Danso, 1987. Graham and Rosas, 1978). Moreover, WUE for okra as it was planted with pea gave significantly higher values as compared with okra sole crop. The highest significant values of WUE were obtained under 1:2 and 2:1 okra / pea row arrangements, where it gave an increase of 0.261 and 0.242 ton/ha/cm over the WUE obtained by okra sole crop. Therefore, the higher yields obtained by okra grown in association with pea could be related to the microclimate modification due to intercropping row arrangements specially light interception, air and soil heat units (Table 1B).

Table 2

The effect of pea / okra intercropping on soil moisture storage (SMS) evapotranspiration (ET) and water use efficiency pea and

A: Pea crop

Row arrangements	SMS cm	ET cm	WUE ton/ha/cm
1 row pea / 1 row okra	24.845 a	26.35 ab	0.353 b
1 row pea/ 2 rows okra	25.765 a	26.22 ab	0.428 a
2 rows pea / 1 row okra	23.935 a	25.54 b	0.431 a
2 rows pea / 2 rows okra	24.947 a	26.82 a	0.368 b
Pea Sole crop	25.315 a	26.80 a	0.287 c

Means followed by the same letter within the same column do not significantly differ using DMRT at 0.05 levels

B: Okra crop

Row arrangements	SMS cm	ET cm	WUE ton/ha/cm
1 row okra/ 1 row pea	23.8 a	23.75 a	0.476 b
1 row okra/ 2 rows pea	23.4 a	24.62 a	0.678 a
2 rows okra/ 1 row pea	24.0 a	24.48 a	0.659 a
2 rows okra/ 2 rows pea	24.02 a	23.43 a	0.641 a
Pea Sole crop	24.18 a	24.42 a	0.417 c

Efficiency of Intercropping

When the values of land equivalent ratio (LER) appear greater than one under intercropping system, this usually indicates the efficiency of this system over the sole cropping system. However, LER is defined as the relative land area under sole cropping that is required to produce the yield achieved in the intercropping. Table 4, shows that when okra and peas were planted under different row arrangements (1:1, 1:2, 2:1, 2:2), the total LER values obtained were higher than one and ranged between 1.16 to 1.58. It is also clear that the efficiency of intercropping was affected by row arrangements. This is logical since each row arrangement allowed the planted crops special local microenvironment, changing to a certain limit the competition for light, moisture and nutrients. The highest relative LERs were obtained when okra was planted with peas under 2:1 and 2:2 row arrangements where okra gave 1.093 and 0.738, respectively. These values are 0.436 and 0.238 higher than expected LER values obtained for okra sole crop planted in two thirds and one half of the land where LER equal to 0.666 and 0.50, respectively. On the other hand, the highest relative LER obtained by peas when it was planted with okra under 2:1 where it gave an increase of 0.29 over the pea sole crop planted in 2/3 of the land.

Table 3

The effect of crop combination and row arrangement on yields of okra and peas during summer growing season of 2002

Intercropping Treatments	Yield Kg ha^{-1} Pea	Yield Kg ha^{-1} Okra
1 Row pea 1 Row okra	9312.7 ab	11303 ab
1 Row pea 2 Row okra	11214 a	16706 a
2 Row pea 1 Row okra	11022 a	16123 a
2 Row pea 2 Row okra	9870.7 ab	15026 a
Pea Sole crop	7701 b	10186 b

Table 4

The relative yields, relative LER and total LER of okra and peas grown under different intercropping row arrangements

Row Arrangements Pea	Row Arrangements Okra	Yield kg ha^{-1} Pea	Yield kg ha^{-1} Okra	Relative LER Pea	Relative LER Okra	Total LER
1 row	1 row	4656.3	5651.5	0.6o5	0.555	1.160
1 row	2 rows	3738	11137.3	0.485	1.093	1.578
2 rows	1 row	7348	5374.3	0.954	0.528	1.482
2 rows	2 rows	4935	7513	0.641	0.738	1.379

The higher efficiency of intercropped okra and peas found in this study agreed with the results obtained by Willey (1979) and Al Qahwaji (1995) who explained this phenomenon by the complimentary use of growth resources over time and space. Moreover, when total LER is considered, the highest values were obtained under 1:2 and 2:1 pea / okra intercropping row arrangements where they gave 1.58 and 1.48 respectively. However, in 1:2 pea / okra intercropping row arrangement, okra gave more contribution than pea, while in 2:1 pea /okra row arrangement, pea gave more contribution than okra. The differences in contribution between okra and peas in such intercropping arrangements might be related to better use of available resources than when they are planted under sole cropping system.

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