December 2009 Volume 4 Issue 6

Trade Science Inc.

Environmental Science
An Indian Journal
Current Research Papers

ESAIJ, 4(6), 2009 [375-384]

Intercropping of kidney bean on corn and its effect on increasing soil productivity per water unit

Evon K.Rizk

Water Requirements Unit, Soil Physics and Chemistry Department, Desert Research Center, El-Mataria, Cairo, (EGYPT)

E-mail : s.sedhom@yahoo.com

Received: 17th June, 2009 ; Accepted: 27th June, 2009

ABSTRACT

A field experiment was conducted during 2008 at El-Sheikh Zuwayid Research station, North Sinai, Egypt. The main objective is to study the effect of intercropping patterns, water quantities and their combined effect on water use efficiency of kidney bean and corn crops. Statistically, this work designed as strip plot design with two variables (five intercropping patterns and three irrigation quantities) and three replicates. The obtained results can be summed up as follows: Increases for kidney bean and corn yields and their components, under intercropping system in the order of (1 bean: 1 corn) > (1 bean: 2 corn) > (2 bean: 1 corn) > (control (sole)). Likewise, both crop yields and their components with the amount of irrigation water in the order of (Q_2 = ETc) > (Q_1 = ETc × 0.8) > (Q_3 = ETc × 1.2). The actual evapotranspiration of kidney bean and corn decreased either with intercropping system in the order of (1 bean: 2 corn) < (2 bean: 1 corn) < (1 bean: 1 corn) < control (sole), or by decreasing irrigation water amounts. Statistical analysis shows significant differences among all treatments. Intercropping system (1 bean: 1 corn) with (Q_1) and (1 bean: 2 corn) with (Q_2) gave the best values of WUE. The investment ratios IR for both treatments gave 1.32 and 1.26 LE of kidney bean and corn, respectively. The study concludes the recommended treatments that could be practiced under North Sinai and similar conditions growing these crops together enable them to thrive and provide high-yield, high-quality crops with a minimum environmental impact.

KEYWORDS

Intercropping;
Water quantities;
Corn;
Kidney bean;
Water use efficiency.

INTRODUCTION

Including legumes in crop rotation is one of the traditional ways to enrich soil with nitrogen through rhyzobium nodules on roots. Therefore, it is expected that intercropping with other kind of crops like cereals; is beneficial. Intercropping of corn with legumes is an alternative to corn monocropping and has several advantages; lower inputs, lower costs of production and better silage quality than the monocrop system[19].

Research on grain yields and yield components of corn and kidney bean in spatially diverse patterns such as strip intercropping can provide insight on crop competition and cropping pattern design. In general, corn and grain sorghum yields increase and soybean yields are lower in border rows of strip-intercropping patterns in temperate regions[3,7,15]. In Indiana, West and Griffith[25] observed 26% increase in corn and 27% reduction in soybean border rows in 8-row alternating strips. In Iowa, Ghaffarzadeh et al.[12] found that strip intercropping had 20 to 24% higher corn yields and 10 to 15% lower soybean yields in adjacent border rows.

Regarding yield component studies in intercropping, Francis et al.[8] found no significant differences in ear diameter, ear length, row number, 100-seed weight, and harvest index of corn between monoculture and intercropping with bush or climbing bean (*Phaseolus vulgaris L.*). They mentioned that efficiency of land use increased with addition of beans to the system, and highest net income was achieved. Willey and Osiru[26] showed corn to have a higher competitive ability at higher populations when intercropped with bean, while for bean it gave lower pod number per plant, with no effect on seed weight. Mohamed et al.[17] found highest biomass yields of intercropped maize and beans and concluded that such intercropping is suitable for producing high-quality silage. Gary and Charles[9] reported that water use efficiency (WUE) was sometimes increased slightly when plants were subjected to water deficits; the data indicate that limited irrigation of corn would not be feasible. Eck[6] found that water deficits during vegetative growth reduced corn kernel number, but had little effect on weight per kernel. Irrigation water use efficiency was found to be between 1.0-2.43 and 0.22-1.25 kg/da–mm, respectively for corn irrigated 6 and 7 times[10,22].

Kernel numbers were not affected by water deficits during grain filling unless severe deficits were imposed early in the period. Harder et al.[13] reported that moisture stress decreases mass/kernel up to 20% depending on the timing of stress in relation to silking date. Also, kernel number is influenced by early stress, with little influence on seed weight.

Doorenbos and Kassam[4] reported good seed yields of kidney bean (*Phaseolus vulgaris*) are between 1.5 and 3.5 ton/ha, the water requirements vary from 300 to 500 mm, and the water utilization efficiency is about 0.8 to 1.6 Kg / m^3.

The aim of this work is to study the effect of some intercropping patterns, water quantities and combined effect on water use efficiency of kidney bean and corn grown in sandy soil at north Sinai, Egypt.

MATERIALS AND METHODS

An experiment was conducted in summer season of 2008 to evaluate the effect of strip intercropping of corn and kidney bean on yields and yield components of the crops in strips and in monoculture and also to study the combined effect of water quantities and intercropping patterns on the water use efficiency of both crops.

Meteorological data for 12 years (1996-2007) were obtained from the local station and used to compute ETo rates using Penman–Monteith equation (TABLE 1), Allen *et al.*[1]. In general, the northeastern part of Sinai Peninsula is characterized by the Mediterranean climate, having hot dry summer and relatively cold winter.

Statistically, this work is designed as strip plot design with two variables; intercropping patterns: (1 bean: 1 corn & 2 bean: 1 corn & 1 bean: 2 corn) and three irrigation quantities: (Q_1 = ETc × 0.8) & (Q_2 = ETc) & (Q_3 = ETc × 1.2) beside the control of both crops and three replicates.

TABLE 1 : Meteorological data of average 12 years (1996-2007) for studied area

Elements	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. Temp. °C	16.64	17.25	19.68	22.98	26.12	29.37	32.10	32.95	31.80	28.50	23.59	19.00
Min. Temp. °C	9.57	9.94	11.54	13.59	15.69	17.92	19.85	20.29	19.44	17.24	14.02	11.04
Relative humidity (%)	81.49	80.49	79.84	78.17	82.21	84.94	86.41	85.34	81.65	83.17	77.28	80.74
Wind speed (km/day)	209.46	236.06	222.44	201.54	179.16	148.00	162.48	137.80	154.20	167.56	191.24	186.32
Sunshine hours (n)	6.98	7.69	8.25	9.35	10.34	11.80	11.88	11.30	10.30	9.15	7.70	6.67
Rain (mm)*	42.43	32.46	20.07	8.23	0.46	0.44	0.10	0.08	0.19	13.97	13.23	42.73
ETo (mm/day)	1.75	2.22	2.94	3.90	4.55	5.24	5.59	5.36	4.68	3.47	2.58	1.81

***Total rain =174.39 mm/year** **ETo = Potential evapotranspiration (mm/day)**

The physical and chemical soil characteristics of the studied site were determined according to Richards (1954), TABLES (2a & b). The soil was sandy and saline with EC of 4.04 dS/, pH of 7.7.

TABLE (2a) : Some physical properties of the soils selected for experimental work

Soil depth (cm)	Particle size distribution (%)				Texture class	Particle density (g/cm^3)	Bulk density (g/cm^3)	Total porosity (%)	Organic matter (%)	Moisture content (%)		Available soil water/layer		Infiltration rate	
	Coarse sand	Fine sand	Silt	Clay						Field capacity	Wilting point	(%)	(mm)	(cm/hr)	Class
0-50	8.21	85.77	2.87	3.15	Sandy	2.52	1.43	43.25	0.23	10.23	2.75	7.48	53.48		
-100	8.18	85.89	2.79	3.14	Sandy	2.57	1.43	44.36	0.24	10.54	3.04	7.50	53.63	16.2	Very rapid
-150	7.91	86.13	2.91	3.05	Sandy	2.52	1.41	44.05	0.22	9.89	2.94	6.95	49.00		

TABLE (2b) : Some chemical and physico-chemical properties of the soils selected for experimental work

Soil depth (cm)	$CaCO_3$ (%)	pH soil paste	ECe (dSm^{-1})	Soluble cations (me/l)				Soluble anions (me/l)				CEC (me/100g soil)	Exchangeable cations (me/100g soil)			
				Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-		Ca^{++}	Mg^{++}	Na^+	K^+
0-50	5.33	7.8	4.00	11.25	10.42	9.15	9.2	0.0	12.35	11.32	16.35	3.02	1.37	0.41	0.72	0.52
-100	5.24	7.7	4.14	12.11	10.98	10.11	8.24	0.0	12.41	11.75	17.28	3.12	1.54	0.47	0.65	0.46
-150	5.45	7.6	3.98	11.85	11.24	8.85	7.88	0.0	12.87	10.54	16.41	3.09	1.63	0.44	0.61	0.41

The chemical analysis of ground water (TABLE 3) used for irrigation by drip system was carried out[21]. The analysis revealed that, this water is saline (3002 ppm), mildly alkaline (pH 7.6) medium sodium, ($C_4 S_2$) and SAR 4.4.

TABLE 3 : Chemical analysis of the well irrigation water of North Sinai research station

P^H	E.C (dS/m)	S.A.R	Soluble cations (meq/l)				Soluble anions (meq/l)				Class
			Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-	
7.6	4.69	4.40	13.26	12.78	15.89	4.98	0	14.35	15.12	17.44	$C_4 S_2$

S.A.R = Sodium adsorption ratio **meq.= ml equivalent per liter**

Soil mixing with orgainc manure by about 20 m^3/fed and calcium superphosphate (15.5 % P_2O_5) at the rate of 31 units/fed were applied during tillage before cultivation of two crops. Kidney bean and corn were no-till planted in a north–south orientation in alternating 6.75 m wide strips (9 rows, 0.75 cm between rows in sole and 1:1 and 50 cm between rows in 1:2 and 2:1 systems), 20 m in length. The experimental units (15) were single strips of 135 m^2; these were sub-sampled for yields and yield components. Seeds of kidney bean were inoculated with the specific strain of Rhyzobium before planting and sown at a rate of 20 kg/feddan sown in lines 15 cm apart between plants on May 16th 2008. After 15 days from sowing, seedlings were thinned to one plant per pit. Fertilization with ammonium nitrate (33.5 % NH_4NO_3) was practiced at the rate of 10 units, (about 25 kg/fed), in three equal doses, after 15 days from sowing, at flowering stage after 45 days from sowing and after 60 days from sowing, potassium sulphate (48 % K_2O) at the rates of 12 units, (about 13 kg/fed) in two equal doses, after 15 days from sowing and at flowering stage after 45 days from sowing.

Corn seeds were planted at a rate of 25 kg/feddan, on June 2 nd. 2008 season, 30 cm apart space hills and thinned to one plant per hill, after 25 days from sowing. Corn plants C.V. K8 were fertilized by N as ammonium sulphate (20.6 % N_2) at the rate of 120 units/fed in three equal doses after 25, 45, and 60 days from planting, and K sulphate (48 % K_2O) at the rate of 48 units/fed in two equal doses after 25 and 45 days from planting. The conventional agricultural practices were used for cultivating of two crops.

Irrigation water amounts were calculated according to Penman –Monteith equation. The irrigation water requirement (TABLE 4) also includes additional water to compensate for non – uniformity of water application and with no leaching requirements.

$D_{iw} = [((ETo \times Kc \times D) \div (1\text{-}LR)) \div E_a] - Pe$ mm[5]

Where: D_{iw} = Applied irrigation water, (mm/m soil)
ETo = References evapotranspiration, (mm/day).
Kc = Crop coefficient.
L.R = Leaching requirements.
Ea = Irrigation system efficiency, (85 %).
D = Root Depth, (mm).
Pe = Effective rainfall = Rainfall × 0.3 (mm).

TABLE 4 : Computed irrigation water amounts (m^3/fed)

Months	May	June	July	August	September	m^3/fed/ season
Bean	35.43	291.39	659.4	459.90	72.11	1518.23
Corn	0.00	116.05	479.62	755.63	485.39	1836.69

Q_1 = 0.8 of the computed amount
Q_2 = 1.0 of the computed amount
Q_3 = 1.2 of the computed amount

In 13th and 30th September 2008 a section of each kidney bean and corn row was hand-harvested in each strip to determine individual row grain yield and yield components.

To determine the actual water consumption soil moisture tension was measured by a tensiometer, and moisture content was determined by weighing method, hence the actual evapotranspiration was calculated by the following equation according to Doorenbos and Pruitt[5]:

$ETa = (M._2 \% - M._1 \%) \times d_b \times D$

Where: ETa = Actual evapotranspiration (mm).
$M._2$ = Moisture content after irrigation (%).
$M._1$ = Moisture content before irrigation (%).
d_b = Bulk density of soil (g / cm^3).
D = Active root depth (m).

At harvest on 13th and 30th September, 2008, after 120 days from sowing of kidney bean and corn plants, yield and yield components were recorded and determined.

The water use efficiency was calculated by dividing the dry seed yield by the amount of seasonal actual evapotranspiration[14]. The investment Ratio (IR) = Output LE / Input LE = costs was also calculated[20]. Data were subjected to the analysis of variance of the split split plot design (ANOVA and L.S.D. at 0.05 and 0.01) according to the method described by Snedecor and Cochran[23].

RESULTS AND DISCUSSION

Kidney bean yields

The effect of some intercropping patterns of bean and corn crops and water quantities on pods, vegetative and total yields of kidney bean, is shown in TABLE 5. The data show that the highest yields correspond to strip-intercropping (1 bean: 1 corn) followed by (1 bean: 2 corn) and (2 bean: 1 corn), while the lowest yields are associated with the control (sole). Significant increases reached 20.2, 10.4 and 5.9 % for pods yield, 16.7, 8.0 and 5.8 % for vegetative yield and 18.7, 9.4 and 5.9 % for biological yield, respectively relative to the control.

Concerning the effect of irrigation water amounts on pods, vegetative and total yields of kidney bean, TABLE 5 reveals that the highest yields were associated with applying irrigation water amount (Q_2 = ETc) followed by (Q_1 = ETc × 0.8), while the lowest ones were associated with (Q_3 = ETc × 1.2). Statistical analysis show highly significant differences among treatments, where the increases reached 8.2 and 4.0 % for pods yield, 7.0 and 4.2 % for vegetative yield and 7.7 and 4.1 % for biological yield, respectively relative to the control.

Regarding the combined effect of both intercropping patterns and water quantities on pods, vegetative and total yields of kidney bean, TABLE 5 shows that the highest yields correspond to strip-intercropping (1 bean: 1 corn) under irrigation with Q_2 followed by (1 bean: 1 corn) under irrigation with Q_1, while the yields are associated with the control (sole) under irrigation with Q_3 for pods, vegetative and total yields of kidney bean. The highest increases over control are 31.9, 27.9 and 30.2 % for pods, vegetative and total kidney bean yields, respectively. Statistical analysis shows highly significant differences mainly rendered to the combined effect of intercropping patterns-water quantities.

Differences kidney bean yield between row positions are less than those in corn–kidney bean intercropping strips, probably due to the slight height difference between the two adjacent crop species in this system. In this connection Wahua and Miller[24] kidney bean yields were reduced 75% in the tall corn intercropping system, but only 17% when intercropped with a semi dwarf corn cultivar; however, they did not distinguish between competition for light and for other resources. In addition significant border-row yield reductions are observed. This suggests that water was the main resource for which competition occurred between those

TABLE 5 : Yield and yield components of kidney bean and corn grown in North Sinai region

Treatments		Bean yield (ton / fed)			Corn yield (ton / fed)		
Intercropping patterns	Water quantities	Pods	Vegetative	Biological	Seed	Straw	Biological
Control (sole)	Q_1(ETc × 0.8)	1.673	1.255	2.928	1.883	2.311	4.194
	Q_2 (ETc)	1.748	1.284	3.032	1.973	2.425	4.398
	Q_3(ETc × 1.2)	1.575	1.168	2.743	1.806	2.225	4.031
Average		1.665 c	1.236 c	2.901 c	1.887 c	2.320 c	4.208 c
1 bean : 1 corn	Q_1(ETc × 0.8)	2.000	1.456	3.456	2.021	2.421	4.442
	Q_2 (ETc)	2.078	1.494	3.572	2.090	2.489	4.579
	Q_3(ETc × 1.2)	1.929	1.377	3.306	1.939	2.354	4.293
Average		2.002 a	1.442 a	3.444 a	2.017 a	2.421 a	4.438 a
2 bean : 1 corn	Q_1(ETc × 0.8)	1.769	1.287	3.056	1.915	2.341	4.256
	Q_2 (ETc)	1.820	1.344	3.164	2.029	2.475	4.504
	Q_3(ETc × 1.2)	1.703	1.291	2.994	1.860	2.271	4.131
Average		1.764 bc	1.307 b	3.071 b	1.935 b	2.362 b	4.297 b
1 bean : 2 corn	Q_1(ETc × 0.8)	1.823	1.345	3.168	1.964	2.426	4.390
	Q_2 (ETc)	1.913	1.365	3.278	2.059	2.532	4.591
	Q_3(ETc × 1.2)	1.779	1.293	3.072	1.918	2.365	4.283
Average		1.838 b	1.334 b	3.172 b	1.980 a	2.441 a	4.421 a
Water quantities	Q_1(ETc × 0.8)	1.816 b	1.336 b	3.152 b	1.946 b	2.375 b	4.321 b
	Q_2 (ETc)	1.889 a	1.372 a	3.261 a	2.038 a	2.480 a	4.518 a
	Q_3(ETc × 1.2)	1.746 c	1.282 c	3.029 c	1.881 c	2.304 c	4.184 c
Intercropping patterns	L.S.D. 0.05 *	0.066	0.040	0.105	0.026	0.026	0.050
	L.S.D. 0.01 **	0.099	0.060	0.159	0.039	0.039	0.076
Water quantities	L.S.D. 0.05 *	0.017	0.010	0.024	0.016	0.018	0.034
	L.S.D. 0.01 **	0.020	0.014	0.033	0.022	0.025	0.047

a, b, c, d, letters indicated significant differences between treatments

two crops of similar plant height. In general, the obtained results coincide well with Pavlish[18] who found kidney bean yield increases in most environments in corn-kidney bean intercropping patterns compared with monoculture. She concluded that these benefits probably occurred because of minimal interference in light interception and a complementary use of other growth resources.

Corn yields

Regarding the effect of intercropping patterns of kidney bean and corn crops and water quantities on seeds, straw and total yields of corn, TABLE 5 shows that the highest yields of seeds and total yields correspond to strip-intercropping (1 bean: 1 corn) followed by (1 bean: 2 corn) and (2 bean: 1 corn), while the lowest yields are associated with the control (sole). However, for straw yield it was (1 bean: 2 corn) followed by (1 bean: 1 corn) and (2 bean: 1 corn). The increases reached 6.9, 4.9 and 2.5 % for seeds yield, 5.2, 4.4 and 1.8 % for straw yield and 5.5, 5.1 and 2.1 % for biological yield, respectively relative to the control. Statistical analysis show highly significant differences and significant increases.

Concerning the effect of irrigation water amounts on seeds, straw and total yields of corn, TABLE 5 reveals that the highest yields were commonly associated with applying irrigation water amount (Q_2 = ETc) followed by (Q_1 = ETc × 0.8), while the lowest yields were associated with (Q_3 = ETc × 1.2). Increases reached 8.4 and 3.5 % for seeds, 7.7 and 3.1 % for straw and, 8.0 and 3.3 % for biological yield, respectively relative to the control. Statistical analysis show highly significant differences and significant increases.

Concerning the combined effect of intercropping patterns and water quantities on seeds, straw and total yields of corn, the statistical analysis placed the two treatments of (1 : 1) and (1 : 2) for bean : corn with Q_2 in unique class where no significant differnces between their data. Both have higher categories than 2: 1 and control treatments.

It seems that the possible reasons for this trend can be distinguished by the following:

1- The nitrogen fixation by the symbiotic, bacteria Rhyzobium on kidney bean root is beneficial to feed corn roots by nitrogen.
2- The discrepancy in root growth character for the two crops dictates that water uptake of corn could actively been from the upper layer, while from the lower layer for kidney bean due to deep root distribution compared to corn roots.
3- Intercropping maximized the shading effect of corn to kidney bean which minimizes the water loss either by evaporation from top soil or transpiration from kidney bean plants. This is reflected on, the net result of minimizing evapotranspiration for the two crops as declared lately.

The highest increases of seeds, straw and total corn yields are about 15.7, 13.8 and 13.9 %, respectively relative to the control. This high grain yield is due to two rows having a suitable space for full light and nutrient absorption. Therefore, this treatment was suitable for high grain production, Asmat et al.[2].

The decreases in the yield with the excess irrigation water amount could be attributed to the partial aeration deficiency in the upper part of root zone which is vital to crop growth. Also, the excess wetting of the top soil may have resulted in leaching out of some nutrients from the root zone. These results agree with previous studies of[7,8,25] who mentioned yield increases in a strip-intercropping system were primarily due to increases in the border rows adjacent to kidney bean.

The obtained results are not in harmony with Francis et al.[8] who compared an intensive corn-bean (*Phaseolus vulgaris* L.) intercropping system with monocultures, and found no significant differences in ear diameter, ear length, row number, 100-seed weight, and harvest index of corn. On the other hand, Willey and Osiru[26] found higher corn yields per plant in an intensive corn–bean mixture than in pure stands; the greatest corn yield increases were found at higher populations. Likewise, West and Griffith[25] found higher yields for intercropped corn at higher populations than in sole-seeded rows.

The results obtained in this paper appear could be explained on basis of the degree of competition experienced mainly for water and light. For instance, corn intercropped had higher values of leaf water potential, stomatal conductance, transpiration and photosynthesis than sole crop[16,25]. Likewise, intercropped bean had higher values of leaf water potential but lower stomatal conductance, transpiration and photosynthesis than sole kidney bean[16].

Actual evapotranspiration

The effect of strip-intercropping bean and corn crops and water quantities on the actual monthly and seasonal evapotranspiration of both crops is shown in TABLE 6.

The data show that the lowest values of the actual seasonal evapotranspiration of kidney bean and corn correspond to strip-intercropping (1 bean: 2 corn) followed by (2 bean: 1 corn) and (1 bean: 1 corn), while the highest values were associated with the control (sole).

Decreases reached 5.4, 3.9 and 1.9 % for the actual evapotranspiration of kidney bean and 7.7, 4.9 and 2.5 % for the actual evapotranspiration of corn, respectively relative to the highest values. Statistical analysis show highly significant differences among treatments.

Concerning the effect of irrigation water amounts on the actual evapotranspiration of kidney bean and corn, TABLE 6 reveals that the actual evapotranspiration decreased by decreasing irrigation water amounts in classic trend. Decreases reached 10.1 and 5.7 % for the actual evapotranspiration of kidney bean and 4.3 and 1.8 % for the actual evapotranspiration of corn, respectively relative to the highest values. Statistical analysis show highly significant differences among treatments.

These criteria can be declared by the effect of intercropping on the mode of water suction from soil profile. The sandy soil maintains a deeper cone of moisture distribution after irrigation. So, the sole treatments benefit from one soil moisture layers; i.e. corn from surface layer and kidney bean from the lower one. However, the intercropping benefits from the two layers simultaneously in plant growth. This means that the water utilized portion in plant growth could be increased under intercropping more than sole treatments. Therefore, the two srip intercropping of 1: 2 and 2: 1 corn: Kidney beans are in the same statistical category c in TABLE 6 of kidney bean, while being d and c of corn as minimum ETa values treatments. Similar results were obtained by Allen et al.[1], Gencoglan and Yazar[10] and Riza et al.[22].

TABLE 6 : Actual evapotranspiration (m^3/fed) of kidney bean and corn grown in North Sinai

Treatments		Bean (ETa m^3/fed)						Corn (ETa m^3/fed)				
Intercropping patterns	Water quantities	May	Jun.	Jul.	Aug.	Sept.	Season	Jun.	Jul.	Aug.	Sept.	Season
	Q_1	57.77	300.41	472.97	272.14	41.48	1144.79c	175.63	420.22	558.25	296.04	1450.13c
Control (sole)	Q_2	70.96	356.54	573.03	329.71	53.61	1383.84b	204.28	488.62	670.24	340.52	1703.66b
	Q_3	75.26	371.39	600.31	366.35	57.44	1470.75a	209.52	494.80	682.11	350.53	1736.96a
Average		68.00	342.78	548.77	322.74	50.84	1333.13a	196.48	467.88	636.86	329.03	1630.25a
	Q_1	55.91	296.12	463.51	267.61	39.82	1122.98	166.38	409.30	570.46	287.20	1433.34
1 bean : 1 corn	Q_2	68.81	351.58	562.11	324.48	49.78	1356.76	193.81	476.25	664.31	330.50	1664.87
	Q_3	73.11	366.44	589.40	355.88	55.53	1440.35	199.04	482.43	670.24	340.52	1692.24
Average		65.94	338.05	538.34	315.99	48.38	1306.70b	186.41	456.00	635.00	319.40	1596.81b
	Q_1	54.04	291.83	454.05	258.54	38.17	1096.63	161.76	398.39	559.99	278.36	1398.50
2 bean : 1 corn	Q_2	66.66	346.63	556.65	314.01	47.87	1331.82	188.57	463.88	652.45	320.48	1625.38
	Q_3	70.96	361.49	578.48	350.65	51.70	1413.27	193.81	470.06	658.38	325.49	1647.74
Average		63.89	333.32	529.73	307.73	45.91	1280.58c	181.38	444.11	623.61	308.11	1557.21c
	Q_1	52.18	287.54	449.33	254.00	36.51	1079.55	152.52	382.02	544.29	265.11	1343.93
1 bean : 2 corn	Q_2	64.51	341.68	551.20	308.78	44.04	1310.20	178.09	451.51	634.66	310.47	1574.72
	Q_3	68.81	356.54	573.03	340.18	47.87	1386.42	183.33	463.88	646.52	320.48	1614.21
Average		61.83	328.58	524.52	300.99	42.80	1258.72c	171.31	432.47	608.49	298.69	1510.96d

Bean: **L.S.D. Intercropping 0.05 = 14.92* & 0.01 = 22.61**** **L.S.D. Water quantities 0.05 = 14.30* & 0.01 = 19.70****
Corn: **L.S.D. Intercropping 0.05 = 24.94* & 0.01 = 37.79**** **L.S.D. Water quantities 0.05 = 7.18* & 0.01 = 9.89****

Water use efficiency (WUE)

The main target of this work is to improve the productivity of water unit for the studied crops under the applied treatments.

A- WUE of kidney bean

Regarding the effect of the tested strip intercropping patterns of kidney bean and corn crops and water quantities on water use efficiency of kidney bean, TABLE 7 shows that the highest values were correspond to strip-intercropping (1 bean: 1 corn) followed by (1 bean: 2 corn) and (2 bean: 1 corn), while the lowest values are associated with the control (sole). In brief the obtained magnitude follows the order: (1 bean: 1 corn) > (1 bean: 2 corn) > (2 bean: 1 corn) > (control (sole)). Increases reached to 22.6, 16.7 and 10.2 %, respectively relative to the control. Statistical analysis shows highly significant differences.

Concerning the effect of irrigation water amounts on water use efficiency of kidney bean, (TABLE 7) reveals that the highest values are commonly associated with applying irrigation water amount (Q_1 = ETc × 0.8) followed by (Q_2 = ETc) while the lowest values are associated with (Q_3 = ETc × 1.2). Increases reached to 15.7 and 14.7 %, respectively relative to the lowest values. Statistical analysis shows highly significant differences.

These results could be explained by the dependance of kidney bean on the deep layers than surface ones. Since the latter layer displayed more evaporation more than the former one.

Concerning the combined effect of some intercropping patterns of kidney bean and corn crops and water quantities on water use efficiency of kidney bean, (TABLE 7) shows that the highest values of WUE correspond to strip-intercropping (1 bean: 1 corn) irrigated by Q_1 followed by (1 bean: 1 corn) irrigated by Q_2, while the lowest values are associated with the control (sole) irrigated by Q_3. The highest value increases by about 43.9 % compared to the lowest value for WUE of kidney bean. Statistical analysis show significant differences.

TABLE 7 : Water use efficiency (kg/m^3) of kidney bean and corn grown in North Sinai

Treatments		WUE kg/m3		Increase %	
Intercropping patterns	Water quantities	Corn	Bean	Corn	Bean
	Q_1(Etc × 0.8)	1.16	1.28	8.5%	18.1%
Control (sole)	Q_2 (ETc)	1.19	1.28	11.3%	17.9%
	Q_3(ETc × 1.2)	1.07	1.09	0.0%	0.0%
Average		1.14 d	1.21 d	0.0%	0.0%
	Q_1(Etc × 0.8)	1.28	1.56	8.6%	15.1%
1 bean : 1 corn	Q_2 (ETc)	1.30	1.55	9.5%	14.3%
	Q_3(ETc × 1.2)	1.18	1.36	0.0%	0.0%
Average		1.25 ab	1.49 a	9.6%	22.6%
	Q_1(Etc × 0.8)	1.25	1.42	7.1%	15.9%
2 bean : 1 corn	Q_2 (ETc)	1.29	1.39	10.6%	13.4%
	Q_3(ETc × 1.2)	1.16	1.22	0.0%	0.0%
Average		1.23 bc	1.34 c	7.8%	10.2%
	Q_1(Etc × 0.8)	1.33	1.48	8.5%	14.0%
1 bean : 2 corn	Q_2 (ETc)	1.35	1.48	10.0%	13.7%
	Q_3(ETc × 1.2)	1.23	1.30	0.0%	0.0%
Average		1.30 a	1.42 b	13.7%	16.7%
	Q_1(Etc × 0.8)	1.26 b	1.44 a	8.2%	15.7%
Water quantities	Q_2 (Etc)	1.28 a	1.42 a	10.3%	14.7%
	Q_3(Etc × 1.2)	1.16 c	1.24 b	0.0%	0.0%

Bean : L.S.D. Intercropping 0.05 = 0.056* & 0.01 = 0.084**
L.S.D. Water quantities 0.05 = 0.022* & 0.01 = 0.030**
Corn : L.S.D. Intercropping 0.05 = 0.032* & 0.01 = 0.048**
L.S.D. Water quantities 0.05 = 0.014* & 0.01 = 0.019**
The calculated WUE values of bean and corn for Doorenbos and Kassam[4] according their results are 1.5 – 2.0 and 0.8 – 1.6 kg/m^3 for fresh seeds yield, respectively.

B- WUE of corn

Regarding the effect of the tested strip intercropping patterns kidney bean and corn crops and water quantities on water use efficiency of corn, (TABLE 7) shows that the highest values of WUE correspond to strip-intercropping (1 bean : 2 corn) followed by (1 bean : 1 corn) and (2 bean : 1 corn), while the lowest values are those of the control (sole). In brief the WUE magnitude is in the order: (1 bean: 2 corn) > (1 bean: 1 corn) > (2 bean: 1 corn) > (control (sole)). Increases reached to 13.7, 9.6 and 7.8 %, respectively relative to the control. It seems important to note that kidney bean could be grown and efficiently use water in yielding high crop with one strip of corn more than two strips, while the reverse is true with corn. This could be explained as follows:

1- In case of (1 bean : 1 corn) kidney bean could easily benefit from the deep water as no competition on water source between the two root systems; i.e. shallow rooting system of corn and deep rooting system of kidney bean.
2- In case of (1 bean: 2 corn) it seems that corn benefits from the nitrogen fixation of kidney bean, with nearly no competition on water source. So, the situation is more favorable to corn than kidney bean in water use efficiency results (TABLE 5).

Statistical analysis show highly significant differences.

Concerning the effect of irrigation water amounts on water use efficiency of corn, (TABLE 7) reveals that the highest values are commonly associated with applying irrigation water amount (Q_2 = ETc) followed by (Q_1 = ETc × 0.8), while the lowest values are associated with (Q_3 = ETc × 1.2). In brief, the magnitude of increasing WUE is in the order: $Q_2 > Q_1 > Q_3$, where the increases reached 10.3 and 8.2 %, respectively relative to the lowest values. Statistical analysis show highly significant differences.

This could be ascribed by the high needs of corn crop to water especially in the surface layers which are more exposed to evaporation.

The combined effect of tested strip intercropping patterns of kidney bean and corn crops and water quantities on water use efficiency of corn is shown in (TABLE 7). The data show that the highest values correspond to strip-intercropping (1 bean: 2 corn) irrigated by Q_2 followed by (1 bean: 2 corn) irrigated by Q_1, while the lowest values are those of the control (sole) irrigated by Q_3. The highest increases by 25.6 % compared to the lowest value for WUE of corn. Statistical analysis show highly significant differences. These findings are in harmony with Doorenbos and Kassam[4], Allen et al.[1], Gencoglan and Yazar[10] and Riza et al.[22].

Economical Assessment

Practically, the economical evaluation of the experimental findings is of a great importance especially in regard to the net return of such treatments which could encourage the farmer to use, or not. In this respect, the investment ratio is computed as a guide where the: Investment Ratio (IR) = Output LE / Input LE, (TABLE 8).

TABLE 8 : Investment ratio (IR) of intercropping corn and kidney bean crops grown in North Sinai region

Economical items	Crops / Field practices	Corn 1 bean : 1 corn Q_1 or Q_2	Bean 1 bean : 1 corn Q_1 or Q_2
List of Inputs, LE/fed	Land preparation, LE/fed	100.0	100.0
	Seeds, LE/fed	125.0	125.0
	Cultivation, LE/fed	100.0	100.0
	Irrigation, LE/fed	367.3	303.6
	Irrigation System Costs, LE/fed	200.0	200.0
	Mineral Fertilizer, LE/fed	150.0	150.0
	Organic Fertilizer, LE/fed	300.0	300.0
	Fertilizer Labors Costs, LE/fed	100.0	100.0
	Pest Control, LE/fed	100.0	100.0
	Weed Control, LE/fed	100.0	100.0
	Machines, LE/fed	100.0	100.0
	Fuel, LE/fed	100.0	100.0
	Harvesting, LE/fed	100.0	100.0
	Crop Transport, LE/fed	100.0	100.0
	Rent (on season), LE/fed	300.0	300.0
	Total Input, LE/fed	2342.3	2278.6
List of Outputs	Seed yield, kg/fed	2021.3	1999.5
	Price, LE/kg	1.50	1.50
	Total Price, LE/fed	3032.0	2999.3
	Net Income, LE/fed	689.6	720.6
	Investment Ratio, LE/ILE	1.29	1.32

The national reported IR value of 1.20 LE

Crop	Control (sole) Q_1(ETc × 0.8)	Control (sole) Q_2 (ETc)	Control (sole) Q_3(ETc × 1.2)	1 bean : 1 corn Q_1(ETc × 0.8)	1 bean : 1 corn Q_2 (ETc)	1 bean : 1 corn Q_3(ETc × 1.2)	2 bean : 1 corn Q_1(ETc × 0.8)	2 bean : 1 corn Q_2 (ETc)	2 bean : 1 corn Q_3(ETc × 1.2)	1 bean : 2 corn Q_1(ETc × 0.8)	1 bean : 2 corn Q_2 (ETc)	1 bean : 2 corn Q_3(ETc × 1.2)
Bean	1.11	1.13	0.98	1.32	1.32	1.19	1.15	1.15	1.04	1.19	1.21	1.09
Corn	1.22	1.23	1.08	1.29	1.29	1.15	1.21	1.24	1.09	1.24	1.26	1.13

Generally, all the tested treatments give higher IR values if compared with the national IR rate or control, except for Q_3. In this context, TABLE 8 shows IR for the highest yield of both corn and kidney bean crops (intercropping 1:1 with Q_1 or Q_2). From the table it is quite clear that:

1- The best treatment of kidney bean yield which correspond to the highest WUE give the highest IR value (1.32) relative to national and control values.

2- The best treatment of corn crops which correspond to the highest WUE give lower IR value (1.29) than kidney bean but still over both national and control values. This trend is in harmony with Francis et al.[8] and Asmat et al.[2].

CONCLUSION

From the aforementioned discussion, it is suggested to cultivate strip-intercropping (1 bean: 1 corn) under irrigation by amounts of water less than that calculated with Penman-Monteith equation by 20% (Q_1) and (1 bean: 2 corn) under irrigation with amounts calculated by Penman-Monteith equation (Q_2) which lead to the best values of both WUE and IR 1.32 and 1.29 LE of kidney bean and corn, respectively.

Accordingly, it is hoped that the current study spots light on the two crops which could be convenience of intercropping of legumes and cereals to magnify the net return of each crop either from the water use efficiency or IR view points.

REFERENCE

[1] R.G.Allen, L.S.Pereira, D.Raes, M.Smith; In: 'Crop evapotranspiration. Guidelines for computing crop water requirements'. Irrig.& Drain.Paper No. 56, FAO, Rome, Italy, **(1998)**.

[2] Asmat Ullah, M.Ashraf Bhatti, Zulfiqar Ali Gurmani, M.Imran; J.Agric.Res. **45(2)**, **(2007)**.

[3] P.Boehner, G.Lesoing, C.A.Francis; 'Strip cropping of grain sorghum/soybeans under dryland and irrigation in eastern Nebraska'. Agron. abs. ASA, Madison, Wisc., USA, **(1991)**.

[4] J.Doorenbos, A.H.Kassam; In: 'Yield response to water'. Irrig.& Drain.Paper No. 33, FAO, Rome, Italy, **(1986)**.

[5] J.Doorenbos, W.O.Pruitt; In: 'Crop water requirements'. Irrig.& Drain.Paper No. 24, FAO, Rome, Italy, **(1984)**.

[6] H.V.Eck; Agron.J. **78**, 1035-40 **(1986)**.

[7] M.C.Fortin, J.Culley, M.Edwards; J.Prod.Agric. **7**, 63-9 **(1994)**.

[8] C.A.Francis, C.A.Flor, M.Prager; Crop Sci. **18**, 760-4 **(1978)**.

[9] W.Lesoinga Gary, A.Francisb Charles; Agron.J. **91**, 807-13, Amer.Soc.Agron. **(1999)**.

[10] C.Gencoglan, A.Yazar; Turkish J.Agric.and Forestry. **23**, 233-41, Ankara, Turkey, **(1999)**.

[11] M.Ghaffarzadeh, F.G.Préchac, R.M.Cruse; Agron.J. **89**, 893-9 **(1997)**.

[12] M.Ghaffarzadeh, F.G.Préchac, R.M.Cruse; Am.J.Altern.Agric. **9**, 171-7 **(1994)**.

[13] H.J.Harder, R.E.Carlson, R.H.Shaw; Agron.J. **74**, 275-8 **(1982)**.

[14] T.Hsiao, P.Steduto, E.Fereres; Irrig.Sci. **25**, 209–31 **(2007)**.

[15] G.W.Lesoing, C.A.Francis; Strip cropping of corn and soybean under dryland and irrigated conditions. Agron.abs.ASA, Madison, Wisc., USA, **(1990)**.

[16] Lima Filho, José Moacir Pinheiro; Physiological responses of maize and cowpea to intercropping. Maize-Cowpea Intercropping Research at Impendhle, **(2005)**.

[17] Mohamed I.Dawo, J.Michael Wilkinson, Francis E.T.Sanders, David J.Pilbeam; The yield and quality of fresh and ensiled plant material from intercropped maize (Zea mays) and beans (Phaseolus vulgaris). Soc.Chem.Indu. Leeds LS2 9JT, UK, **(2007)**.

[18] L.A.Pavlish; Influence of intercropping patterns on yields of sorghum and soybeans. Lincoln: M.Sc. thesis. Univ.Nebraska, USA, **(1989)**.

[19] B.Prithiviraj, K.Carruthers, Q.Fe, D.Cloutier, R.C.Martinand, D.L.Smith; Intercropping of corn with soybean and lupine for silage: Effect of seeding date on yield and quality. J., Paper no. J-16919, Iowa Agric.Home Econo.Exp.Stn., Ames. Project no. 2910, **(1996)**.

[20] G.Rana, N.Katerji, M.Mastrorilli, C.R.Camp, E.J.Sadler, R.E.Yoder; Evapotranspiration measurement of crops under water stress: Evapotranspiration and irrigation scheduling. Proc.Int.Conf., San Antonio, Texas, U.S.A., November 3-6, 691-6 **(1996)**.

[21] L.A.Richards; 'Diagnosis and improvement of saline and alkali soils'. Agric.Handbook No. 60. U.S. Salinity Lab. Washington D.C., U.S.A, **(1954)**.

[22] Riza Kanber, Mustafa Ünlü, Burcak Kapur, Levent Koç, Sultan Kýymaz, Erol H.Cakmak, Mekin Tüzün; Country Report: Water Use Efficiency in Turkey. WASAMED. Thematic Network, **(2005)**.

[23] G.W.Snedecor, W.G.Cochran; 'Statistical Methods'. 7th Ed. Iowa, State Univ., Press, Ames., Iowa, U.S.A., 593, **(1989)**.

[24] T.A.T.Wahua, D.A.Miller; Agron.J., **70**, 287-91 **(1978)**.

[25] T.D.West, D.R.Griffith; J.Prod.Agric. **5**, 107-10 **(1992)**.

[26] R.W.Willey, D.S.Osiru; J.Agric.Sci. **79**, 517-29 **(1972)**.