Water Conservation and Yield Advantage from Intercropping Maize with Peanut

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Abstract

In the sandy soil of Egypt, the most limiting factor is water (rainfall and irrigation) availability, and it is thus necessary to improve Water Use Efficiency (WUE) and Land Equivalent Ratio (LER). The key can be found in intercropping. It is interesting that shade manipulation by associated crops in intercropping increase crop water use of dominant crops because of a reduction in evaporation from soil. Peasants or small-scale farmers have practiced intercropping since old times. A reason for this popularity is built on facing food shortage; resource maximization and profit also play an important role. Since, peanut (Understory crop) is the main crop; preferably, occupying the whole cultivated area of sandy soil, the geometrical distribution of maize (Shade or overstory crop) is expected to play an important role to maximize production, WUE and net return of the intercrop per unit area of land. The purpose of the study was to find the optimal (peanut: maize) intercropping pattern, which maximizes the net return for small-scale farmers from sources unit (Water and Land), i.e., same peanut land area and irrigation water to replenish part of maize gap in Egypt by increasing our production and decreasing our imports due to using maize grains to produce bio-fuel in rich countries.Two field experiments were carried out to study the interaction effect of intercropping patterns: peanut: maize (2:1), (1:1) and (1:2); distribution of maize plants: spacing maize plants at 35cm. apart with one plant/hill or at 70cm. apart with two plants/hill and nitrogen fertilizer rates: 140, 210 and 280 Kg N ha-1. Pure stand plots of both peanut and maize were included in each replicate for Land Equivalent Ratio (LER) and net return essays. Treatments were assigned randomly in factorial Randomized Complete Block Design (RCBD) and replicated for four times. Peanut cv Giza 5 was planted with an intra spacing of 10cm. apart on one side of the ridges when intercropped or in pure stand, whereas maize cv single cross 10 was spaced at 35cm. apart with one plant/hill in pure stand only. Results showed that all intercropping patterns had higher values of W.U.E. than when growing peanut in pure stand in both seasons. Highest W.U.E. was obtained from (1:2) pattern which distributed at 70cm. apart leaving two plants/hill and adding 280 Kg N ha-1 for the intercrop. From another angle of data increasing of maize density to 67% in (1:2) pattern in same time decreasing peanut pod yield (main crop) to the lowest value which stimulate the need to stop increasing maize density at 50% in (1:1) pattern which resulted in balance point among WUE, LER and Net return. The results obtained have led to the conclusion and recommendation that intercropping peanut grown under 50% of full maize stand (2.4 plants/m2) in (1:1) pattern distributed at 70cm. apart leaving two plants/hill and adding 280 Kg N ha-1 for the intercrop resulted in maximum net return of 766.46 and 916.80 US $ ha-1 and maximum LER of 1.44 and 1.41 with increasing in WUE of 111.11 and 138.71% over the pure stand of peanut in first and second season, respectively.

Keywords: Intercropping, Peanut, Maize, WUE, LER.

Introduction

Over-population, low food production and limited water and arable land are causes of food insecurity in Egypt as well as other developing countries. Intercropping may be one of the most important means for intensifying the agricultural system. This is an obligate task in developing countries where small-scale farmer manages intensively a limited land area (Francis, 1986). Intercropping, in Egypt, is also recommended to increase profitability for Egyptian farmers (Metwally *et al*, 2005).

Yield advantage of intercropping is based theoretically on three biological concepts; differences in morphological characteristics, the physiological nature of both crops involved in the mixture (Bull, 1979) and the compatibility of cultural practices of crops in the associations (Kamel *et al*, 1990). Medium to short plant height is desirable in most legumes as in maize-peanut systems. Height differences between the two components in the mixture may be more important than the absolute height of either component. In crop mixtures, the combination of two or more crops with different rooting systems such as a shallow-rooted species with a deep rooted species should give a better total water and nutrient extraction potential than either crop grown sole (Krantz, 1974).

The physiological nature of both crops involved in the mixture has shown the ability of C_4 crop such maize to utilize higher light intensities (till 10.000 foot candle/square meter) rather than C_3 crop such peanut. Almost species of temperate origin are associated with greater affinity for CO_2 at the carboxylation site, which might explain the maximizing benefits of land unit area, especially when a taller growing crop is associated with a short understory crop. Moreover, the spatial arrangement of both components provide more light interception by foliage of C_4 crop (the taller component) whereas, C_3 crop emerge large CO_2 quantities essential for the C_4 plants to develop higher gross photosynthesis.

The improvement of crop productivity from sources unit (Water and Land) is the common aim of agriculturists to decrease Egypt imports from strategic crops as maize which reach up to 2429.28 M.T. equal 367.33 Million US $ *(Arab organization for agriculture development, 2004)*.

Several years have been devoted on elaborative research in order to figure out the most productive intercropping pattern. However, the appropriate decision and the correct choice of the most biologically efficient pattern of peanut-maize association have not been reached. Therefore, the objective of the present study is to investigate the interrelationship of peanut-maize intercropping patterns, the geometric and plant density of maize (the shade crop) and the effect of various rates of nitrogen fertilization in sandy soil from same sources unit compared with sole planting of the two crops.

Materials and Methods

Two field trials were carried out at Ismaillia Agricultural Research Station, Agricultural Research Center (ARC) (2003 and 2004 seasons) in a sandy soil, to study the interaction effect of intercropping patterns, distribution of maize plants and nitrogen fertilizer rates on yield and yield component traits of peanut and maize in the intercrop and assay Water Use Efficiency (WUE), Land Equivalent Ratio (LER) and net return between both components in the intercrop. Eighteen treatments were the combinations of: 1- Three intercropping patterns (Peanut was grown on all ridges and maize was grown on the other side of: a- The third ridge in (2: 1) pattern - 100% peanut and 33% maize, b- The second ridge in (1: 1) pattern - 100% peanut and 50% maize and c- The second and third ridges in (1: 2) pattern - 100% peanut and 67% maize), 2- Two distribution systems of maize plants (Maize thinned to: a- One plant/hill and 35cm. apart. and b- Two plants/hill and 70cm. apart.) and 3- Three nitrogen fertilization rates (140, 210 and 280 Kg N ha^{-1}.). Pure stand plots of both peanut and maize were included in each replicate for WUE, LER and net return essays. Both treatments were not involved in the statistical analysis.

Plot area was $12.6m^2$ and consisted of 6 ridges, each was 3.5m. in length and 0.6m. in width.

The soil was sandy textured (67.98% coarse sand, 24.56% fine sand, 3.13% silt and 4.33% clay), with 7.8 pH, 0.47% organic matter content, 18.21 ppm available N, 2.19 ppm available P and 73.98 ppm available K . (Average of the two seasons).

Peanut cv. Giza 5 (Main crop – understory crop) was seeded on 23rd and 25th May in 2003 and 2004 seasons, respectively, whereas maize cv. single cross 10 (Shade crop – overstory crop) was seeded after two weeks from peanut planting date. Two sprinkler irrigations were carried out every week and all treatments were irrigated as recommended for peanut in pure stand. Peanut was seeded with intra spacing of 10cm. apart on one side of the ridges with population of (166666 plants ha^{-1}.) when intercropped or in pure stand. Whereas, maize was planted according to the treatment imposed. Phosphatic fertilization was added during land preparation at the rate of 71 Kg P_2O_5 ha^{-1}. in the form of Calcium Super Phosphate (15.5% P_2O_5). Nitrogen fertilization was applied at the rates of 140, 210 and 280 Kg N ha^{-1}. in the form of Ammonium Sulphate (20.5% N). Application of nitrogen fertilizer was in six equal split up doses. The first dose was after three weeks from peanut planting date and other doses were every week after the provirus one. Potassic fertilization was applied at the rate of 57 Kg K_2O ha^{-1}. in the form of Potassium Sulphate (48% K_2O) with the fourth dose of nitrogen fertilization. Harvesting of peanut was after 120 days from seeding peanut and maize was after 120 days from seeding maize in both seasons.

Data Recorded:

1. Peanut pod yield ha^{-1} (ton).
2. Maize grain yield ha^{-1} (ton).

Calculations of intercropping evaluation:

1. Water Use Efficiency "WUE" (Kg/m^3)

   WUE = Yield (Kg ha^{-1}) / total applied water (m^3 ha^{-1}), Sherif, Sahar *et al* (2006).

2. Land Equivalent Ratio (LER):

   LER determined as the sum of the fractions of the yield of the intercrops relative to their sole crop yields according to the following formula (Willey, 1979):

   $LER = [(Y_{ab}/ Y_{aa}) + (Y_{ba}/ Y_{bb})]$

   Where:

   - Y_{aa} and Y_{bb} means: Pure stand yield of crop (a) and (b), respectively.
   - Y_{ab} and Y_{ba} means: Intercrop yield of crop (a) and (b), respectively.

3. Net return ha^{-1}**:**

   Net return was calculated for each treatment in the US \$ ha^{-1} for peanut and maize in intercropping or in pure stand according to Anonymous (2004 and 2005) for both years.

Statistical analysis:

Data were analyzed using ANOVA in factorial Randomized Complete Block Design (RCBD) with four replications. MSTAT-C (1988) was used for statistical computations.

Results and Discussion

1. Effect of intercropping patterns:

Results in Table (1) indicate clearly that highest value of peanut pod yield trait was evident when peanut was grown under 33% of full density of maize (1.6 $plant/m^2$) in (2:1) pattern. These results were true in both seasons. Several investigators support these results such as Abd El-Motaleb and Yousef (1998) and Metwally *et al* (2005).

Results on maize grain yield followed reversed trend of the pattern treatment effect on peanut pod yield. Indicating that the maize grain yield was associated with maize density in the intercrop rather than any other factor. These results are in agreement with those obtained by several investigators such as Lucas (1986) and El-Bana and Gomaa (2000).

Table (1): Effect of intercropping patterns on pod yield and grain yield traits in 2003 and 2004 seasons.

Traits / Intercropping patterns	Peanut pod yield ha^{-1} (Ton)		Maize grain yield ha^{-1} (Ton)	
	First season 2003	Second season 2004	First season 2003	Second season 2004
100% peanut : 33% maize (2:1)	2.52 A	2.17 A	2.79 C	3.17 C
100% peanut : 50% maize (1:1)	2.40 B	2.02 B	3.67 B	4.17 B
100% peanut : 67% maize (1:2)	2.05 C	1.71 C	4.43 A	4.88 A

2. Effect of distribution of maize plants:

Results in Table (2) indicate that pod yield trait was influenced by the geometric distribution of maize plants. Values of these traits when maize plants were spaced at 70cm. apart and leaving two plants per each hill were ever superior to those spaced at 35cm. and leaving one plant/hill.

In explicit, these results evidenced that reductions in values of these traits were tenaciously bounded with narrowing maize spacing which resulted in more shading Calavan and Weil (1988), support the conclusion that the within-row maize spacing treatments significantly affected light availability to peanut plants.

In addition Hardy and Havelka, (1973), reported that shading reduces the rate of peanut photosynthesis and affects the amount of assimilates available for the competing processes of N_2 fixation and reproductive dry matter accumulation. They also found that peanut root nitrogenase activity was 30 to 46% lower for intercrop than for sole crop.

Table (2): Effect of distribution of maize plants on pod yield and grain yield traits in 2003 and 2004 seasons.

Traits / Distribution of maize plants	Peanut pod yield ha^{-1} (Ton)		Maize grain yield ha^{-1} (Ton)	
	First season 2003	Second season 2004	First season 2003	Second season 2004
35 cm apart (one plant/hill)	1.98 B	1.69 B	3.76 A	4.28 A
70 cm apart (two plants/hill)	2.67 A	2.26 A	3.50 B	3.88 B

Results on grain yield followed reversed trend of the geometric distribution of maize plants effect on pod yield. Indicating that diminishing effect was a result of intra-specific competition among maize plants when two plants were left per hill.

3. Effect of nitrogen fertilizer rates:

Results presented in Table (3) indicated that there were ever increases in the values of pod and grain yields with increasing the rate of nitrogen fertilizer. These results were true in both seasons and supported by several investigators such as El-Douby *et al* (2001), Hussein, Samira (2005) and Lanier *et al* (2005).

Table (3): Effect of nitrogen fertilizer rates on pod yield and grain yield traits in 2003 and 2004 seasons.

Traits / Nitrogen fertilizer rates	Peanut pod yield ha^{-1} (Ton)		Maize grain yield ha^{-1} (Ton)	
	First season 2003	Second season 2004	First season 2003	Second season 2004
140 Kg ha^{-1}	2.14 C	1.83 B	3.26 C	3.81 C
210 Kg ha^{-1}	2.38 B	2.02 A	3.64 B	4.09 B
280 Kg ha^{-1}	2.43 A	2.07 A	3.98 A	4.31 A

Patra and Poi (1998) revealed that intercropping caused the number of nitrogen fixing nodules on the legume crop roots to decrease due to shading. When legume was intercropped with cereals, legume nodulation was poor and less nitrogen fixation took place. On this basic ground, it could be concluded that *First:* intercropping peanut with maize might stimulate the peanut plant response to increased rates of nitrogen fertilizer rather than growing peanut in mono culture due to the inhibitory effect of maize shading on peanut nodulation, (Senaratne and Ratnasinghe, 1993). *Second:* that the poor natural population of rhizobia in the sandy soil was offset by high response of peanut to increased nitrogen fertilizer level might explain different response to the nitrogen fertilizer level. These conclusions were also explained by Senaratne and Ratnasinghe (1993).

4. Interaction effects:

A summary of the interaction effects of the three experimental factors is given in Table (4). In this table the highest values of traits studied are given. The letters in brackets represent the sequence in the order of the planting practices (intercropping patterns × distribution of maize plants × nitrogen fertilizer rates). From the table it is clear that the highest values of pod yield was recorded when maize percent in the intercrop diminished to one third of its full stand in (2:1) pattern, when only growing maize at 70cm. apart and leaving two plants/hill and received 280 Kg N ha^{-1}. while grain yield ha^{-1}. reached maximum when maize percent in the intercrop increased to 67% of its full stand in (1:2) pattern when only growing maize at 35cm. apart and leaving one plant/hill and received also 280 Kg N ha^{-1}. These conclusions were also explained by Hussein, Samira (2005), Kamel, *et al* (1990) and Metwally, *et al* (2005).

Table (4): Summary of interaction effects among intercropping patterns (A), distribution of maize plants (B) and nitrogen fertilizer rates (C) on pod yield and grain yield traits in 2003 and 2004 seasons.

Treatments \ Traits	Peanut pod yield ha^{-1} (Ton)		Maize grain yield ha^{-1} (Ton)	
	First season 2003	Second season 2004	First season 2003	Second season 2004
A×B	* $(A_1 \times B_2)$ 2.88	* $(A_1 \times B_2)$ 2.48	* $(A_3 \times B_1)$ 4.45	* $(A_3 \times B_1)$ 4.95
A×C	* $(A_1 \times C_3)$ 2.64	* $(A_1 \times C_3)$ 2.26	* $(A_3 \times C_3)$ 4.81	* $(A_3 \times C_3)$ 5.19
B×C	* $(B_2 \times C_3)$ 2.79	* $(B_2 \times C_3)$ 2.36	* $(B_1 \times C_3)$ 4.12	* $(B_1 \times C_3)$ 4.50
A×B×C	*$(A_1 \times B_2 \times C_3)$ 3.02	*$(A_1 \times B_2 \times C_3)$ 2.59	*$(A_3 \times B_1 \times C_3)$ 4.86	*$(A_3 \times B_1 \times C_3)$ 5.21

5. Water Use Efficiency (WUE):

Results in Table (5) showed that all intercropping patterns had higher values of W.U.E. than when growing peanut in pure stand and lower values of W.U.E. than when growing maize in pure stand in both seasons. Sherif, Sahar *et al* (2006) supported these results.

Highest W.U.E. was obtained from (1:2) pattern which distributed at 70cm. apart leaving two plants/hill and adding 280 Kg N ha^{-1} for the intercrop. From another angle of data increasing of maize density to 67% in (1:2) pattern in same time decreasing peanut pod yield (main crop) to the lowest value which stimulate the need to stop increasing maize density at 50% in (1:1) pattern which resulted in balance point among WUE, LER and Net return.

6. Land Equivalent Ratio (LER):

Land Equivalent Ratio values in Table (5) indicated clearly that all values obtained under the treatment imposed exceeded the unit indicating yield advantage as compared when each component was grown alone. These results were true in both seasons. The only exception, was when maize density diminished to 33% (2:1) and peanut was shaded by maize spaced 35cm. apart leaving one plant/hill and the plot received lowest nitrogen fertilizer rate (140 Kg N ha^{-1}.) in the first season only where LER was less than the unit with no yield advantage being achieved. Results of the interaction indicate that LER obtained from (1:1) pattern were generally superior to (2:1) or (1:2) pattern either. Moreover, LER values of (1:2) pattern were always higher than in (2:1) pattern under same respective nitrogen fertilizer dose. (2:1) pattern recorded lowest values. LER values also increased with increasing the nitrogen fertilizer level. Within distribution patterns of the shade crop LER of 70cm. spaced plants and two plants/hill were left were relatively higher than those spaced at 35cm. spaced and one plant/hill, due to increasing light efficiency and decreasing the shading effect on the understory crop.

Maximum LER was obtained when the intercrop received 280 Kg N ha^{-1}. and peanut plants were grown under the 50% of maize plants (2.4 plants/m^2) distributed at 70cm. apart and two plants/hill were left in (1:1) pattern.

Yield advantage in the intercrop as compared with sole cropping were also supported by Calavan and Weil (1988) who found that peanut-maize intercrop resulted in land equivalent rate ranging from 1.28 to 1.49, Eliseu and Freire (1992) who also found that peanut-maize intercrop gave yield advantage estimated to 1.20-1.99, particularly in peanut-maize (3:1).

7. Net return:

Results on net return presented in Table (5) also indicated that the treatment effect had apparent impose on net return with increases in nitrogen fertilizer level from 140 to 280 Kg N ha^{-1}. under all the intercrop patterns. The results also evidenced that within any intercrop, net return (on average basis) when peanut plants were grown at 70cm. spaced maize plant with two plants/hill were higher than those distributed at 35cm. spaced maize plant leaving one plant/hill. Maximum net return was recorded when the intercrop plots received 280 Kg N ha^{-1}. and peanut plants were grown under 50% of full stand of maize plants distributed at 70cm. apart with two plants/hill. Whereas, when the intercrop plot received 280 Kg N ha^{-1}. and peanut was grown under 67% of full stand of maize plants distributed at 70cm. apart with two plants/hill had the second net return indicating that increasing the shade crop density to maximum, 67% (3.2 plants/m^2) had no any beneficial effect whether on production per unit of land (measured in LER) or any more economical value (measured in net return).

Table (5): Effect of intercropping patterns, distribution of maize plants and nitrogen fertilizer rates on Water Use Efficiency (WUE), Land Equivalent Ratio (LER) and Net Return in 2003 and 2004 seasons.

Treatments \ Traits			WUE (Kg/m^3)		LER		Net Return (US $)	
Intercropping patterns	Distribution of maize plants	N rates (Kg ha^{-1})	First season 2003	Second season 2004	First season 2003	Second season 2004	First season 2003	Second season 2004
100% : 33% (2:1)	35 cm apart (one plant/hill)	140	0.52	0.56	0.99	1.03	376.25	568.23
		210	0.58	0.60	1.10	1.13	472.64	657.52
		280	0.62	0.62	1.17	1.16	498.32	658.28
	70 cm apart (two plants/hill)	140	0.56	0.56	1.16	1.18	597.88	716.19
		210	0.62	0.60	1.28	1.27	700.65	788.40
		280	0.66	0.63	1.34	1.30	726.09	809.32
100% : 50% (1:1)	35 cm apart (one plant/hill)	140	0.60	0.64	1.07	1.11	410.12	659.14
		210	0.67	0.70	1.19	1.21	501.78	749.99
		280	0.71	0.73	1.26	1.26	531.53	773.40
	70 cm apart (two plants/hill)	140	0.64	0.65	1.23	1.25	613.33	791.49
		210	0.71	0.71	1.37	1.36	730.21	889.79
		280	0.76	0.74	1.44	1.41	766.46	916.80
100% : 67% (1:2)	35 cm apart (one plant/hill)	140	0.63	0.67	1.06	1.08	330.68	605.19
		210	0.70	0.73	1.19	1.19	428.07	699.65
		280	0.75	0.75	1.25	1.22	450.13	716.00
	70 cm apart (two plants/hill)	140	0.69	0.71	1.24	1.23	541.88	765.53
		210	0.76	0.77	1.37	1.35	649.24	882.43
		280	0.81	0.81	1.43	1.40	682.23	915.25
Pure stand of peanut			0.36	0.31	-	-	580.36	498.11
Pure stand of maize			1.29	1.43	-	-	219.86	726.54

- Pure stands**:** 3.24, 2.79 ton pods ha^{-1}. and 7.07, 7.83 ton grains ha^{-1}. for 2003 and 2004 seasons respectively.
- Ton prices**:** (Peanut pods = 371.01 and 391.88 US $) & (Maize grains = 120.50 and 180.12 US $) for 2003 and 2004 seasons respectively.

However, it could be concluded that differences were only appreciable between (1:1) and (1:2) or (2:1) patterns which stimulate the need to more plant density of maize to improve the net return of the intercrop particularly if the price unit of the shade crop increased, i.e., increasing the shade crop up to 67% or decreasing it to 33% of its full stand density is mainly dependant on the price unit of the shade crop.

Conclusion

The results obtained have led to the conclusion and recommendation that intercropping peanut grown under 50% of full maize stand (2.4 plants/m^2) in (1:1) pattern distributed at 70cm. apart leaving two plants/hill and adding 280 Kg N ha^{-1} for the intercrop resulted in maximum net return of 766.46 and 916.80 US \$ ha^{-1} and maximum LER of 1.44 and 1.41 with increasing in WUE of 111.11 and 138.71% over the pure stand of peanut in first and second season, respectively.

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