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Evaluation of Competitive Indices between Roselle and Cowpea as Influenced By Intercropping System and Bio-Fertilization Type

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ABSTRACT

This investigation was carried out at the Agriculture Experimental Farm of Faculty of Agriculture, Zagazig University during the two successive summer seasons of 2014 and 2015 aiming to evaluate different competitive indices between okra and cowpea as affected by intercropping systems; viz., 1:1, 1:2, 1:3 and 2:3 as well as sole planting of each crop and different biofertilization types (*Azotobacter*, *Rhizobium*, a mixture of the two types of the biofertilizers and uninoculated control) and their combination treatments. A split plot experiment in a randomized complete blocks design was used in this search with three replications. Competition indices; viz., land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity (A) and land utilization efficiency (LUE) revealed that, all applied intercropping systems and biofertilizers types as well as combination treatments were more efficient than sole cropping. Aggressivity estimation indicated that roselle was dominant while cowpea was dominated. The highest values of the above mentioned competition indices were belonged to intercropping system of 2:3 roselle and cowpea fertilized with *Azotobacter* as biofertilization alone. This treatment seemed to be promising for high economic return.

Key words: Roselle, cowpea, intercropping system, biofertilizers, competitive indices

Introduction

Roselle (*Hibiscus sabdariffa* L.), an annual shrub, is commonly used to make jellies, jams and beverages. Roselle has also many medicinal properties since it is used as digestive, choleretic, antibilious, laxative, diuretic, hypotensive, antiscorbutic. The seeds contain sterols, including 3.2% ergosterol (Khare, 2007).

Cowpea (*Vigna unguiculata*, L.; Walp) is an important grain legume in Egypt, is commonly cultivated as a nutritious and highly palatable food source in the southern United States, Africa, Asia, and the tropics and subtropics. The leaves and flowers may also be consumed. The seed is found to contain 24% crude protein, 53% carbohydrates, and 2% fat (FAO, 2012). Cowpea grows rapidly and reaching a height of 19–24 inches (48–61 cm) when grown under a good conditions (Singh *et al.*, 2003).

Multiple cropping has been practiced for centuries by small-scale farmers in Africa to reduce the risk of crop failure, attain higher yields, and to improve soil fertility (Litsinger and Moody, 1976). Intercropping, through more effective use of water, nutrients and solar energy, can significantly enhance crop productivity compared to the growth of sole crops (Midmore, 1993).

Various indices such as land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity (A) and land utilization efficiency (LUE), have been developed to describe the competition and possible economic advantage in intercropping (Mead and Willey, 1980; Hiebesch and McCollum, 1987 and Ghosh, 2004). Mathematical indices can help researchers to summarize, interpret, and display the results from plant competition trials (Weigelt and Jolliffe, 2003). Indices can express various attributes of competition in plant communities, including competition intensity, competitive effects, and the outcome of competition (Agegnehu *et al.*, 2006).

They are commonly called microbial inoculants or biofertilizers which are capable of mobilizing important nutritional elements in the soil from non-usable to usable form by the crop plants through their biological processes. In the last decade biofertilizers were used extensively as an eco-friendly

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approach to minimize the use of chemical fertilizers, improve soil fertility status and enhance crop production by their biological activity in the rhizosphere. Bio-organic farming today has become of great importance for sustainable agriculture, limiting deterioration of the agricultural lands and environment, producing safer crop products for human and animal consumption and increasing possibility of biological control of harmful insects and soil-borne pathogens Gomaa *et al.* (2002). Biofertilizers are in fact the living microorganisms, which are able to fix atmospheric nitrogen and convert it into usable form for plants (Rao 1995 and Vessy 2003).

The present study was designed to evaluate the effect of intercropping system and biofertilization type on different competition (*i.e.*, LER , ATER, A and LUE) indices in roselle-cowpea intercropping systems for better resources management and higher crop productivity.

Materials and Methods

The present study was conducted at the Agriculture Research Farm, Faculty of Agriculture, Zagazig University, Egypt during the two successive summer seasons of 2014 and 2015, to investigate the effect of intercropping systems of roselle (cv. Dark red) and cowpea (cv. Cream 7) on growth parameters, yield and its components and some chemical constituents of roselle and cowpea under Sharkia Governorate conditions.

The physical and chemical properties of the experimental soil site are shown in Table 1, according to Chapman and Pratt (1978).

Table 1: Physical and chemical properties of experimental soil

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Sandy clay
43.39	9.26	13.62	33.73	

Chemical analysis												
pH	EC m.mohs / cm	Organic mater (%)	Soluble cations (meq. / L)				Soluble anions (meq. / L)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.82	0.98	0.58	2.7	1.6	1.7	4.1	4.5	1.7	3.5	17	83	71

This experiment included 24 treatments, which were the combinations between six intercropping systems and four biofertilizers types which were; control (without inoculation), *Azotobacter chroococcum*, *Rhizobium Leguminsarum* and a mixed biofertilizer containing equal parts of both types (1×10^6). Source of biofertilization type was Microbiology Department, Faculty of Agriculture, Zagazig University. The intercropping system treatments were as follows:

1- and 2- Sole cropping systems of each roselle and cowpea. Such treatment was used as control for both crops.

3- Intercropping system of 1:1; since planting one row of roselle alternated with one row of cowpea. Such pattern provides the proportional area of 50: 50 of each roselle and cowpea, respectively.

4- Intercropping system of 1:2; since planting one row of roselle alternated with two rows of cowpea. Such pattern provides the proportional area of 33.3: 66.7 of each roselle and cowpea, respectively.

5- Intercropping system of 1:3; since planting one row of roselle alternated with three rows of cowpea. Such pattern provides the proportional area of 25: 75 of each roselle and cowpea, respectively.

6- Intercropping system of 2:3; since planting two rows of roselle alternated with three rows of cowpea. Such pattern provides the proportional area of 40: 60 of each roselle and cowpea, respectively.

These treatments were arranged in a split plot in randomized complete blocks design with three replicates. Intercropping systems were randomly arranged in the main plots and biofertilizers types were distributed randomly in the sub plots. The plot area was 14.4 m^2 (2×7.20 m) included twelve rows; each row was 60 cm apart and two meters in length. The seeds were sown on row in hills on one side. The distances between hills were 30 cm for roselle and 20 cm for cowpea plants.

Seeds of roselle (*Hibiscus sabdariffa* L.) cv dark red were obtained from Agriculture Research Centre (ARC), Dokky, Giza. The source of cowpea seeds (*Vigna unguiculata*, L) cv. Cream 7 were

Mecca Trade Co., Cairo, Egypt. Seeds of both roselle and cowpea crops were sown on 15th May of both seasons. Seeds inoculated with biofertilizers types by used arabic gum (16%) as an adhesive agent. Seeds were sown by hand then immediately irrigated. After three weeks from sowing, seedlings were thinned to be one plant / hill for both crops. All the plants received normal agricultural practices whenever they needed.

The outer two rows (1st and 12th) of each plot were considered as a belt. Samples were taken from guarded plants in center of each plot.

Dry pods of cowpea were harvested after 120 days of seed sowing and the seed yield/fad. (kg) of cowpea was calculated. After 160 days from sowing of roselle the yield of sepals was harvested and the air dry sepals yield/fad. (kg) was calculated.

Competitive relationships were calculated as follows:

1. Land equivalent ratio (LER):

This parameter gives an indication to the relative land area required, as sole cropping, to produce the same yields achieved by intercropping. When the LER is greater than one, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than one the intercropping negatively affects the growth and yield of the intercropped plants. It was determined for roselle and cowpea yields recorded per feddan according to Mead and Willey (1980) equation as follows:

LER roselle.cowpea = Lr + Lc ,

$$Lr = \frac{Yrc}{Yrr} \quad , \quad Lc = \frac{Ycr}{Ycc}$$

Where:

Lr and Lc are the relative yield of roselle and cowpea, respectively. Yrr and Ycc are the yields per feddan of roselle and cowpea sole crops, respectively. Yrc and Ycr are the yields of roselle and cowpea, respectively, as intercrops.

2. Area time equivalent ratio (ATER):

It was calculated according to Hiebsch and McCollum (1987) equation as follows:

$$ATER = \frac{Yrc/Yrr \times tr + Ycr/Ycc \times tc}{T}$$

Where:

Yrc = intercropped yield of roselle, Yrr = sole yield of roselle, Ycr = intercropped yield of cowpea, Ycc = sole yield of cowpea, tr = the duration of roselle in days, tc = the duration of cowpea in days, and T= the total duration of intercropping system in days.

3. Land utilization efficiency (LUE%):

By using LER and ATER values, the land utilization efficiency (LUE %) was calculated according to Mason *et al.* (1986) equation as follows:

$$LUE = \frac{LER \times ATER}{2} \times 100$$

4. Aggressivity (A):

Aggressivity value was calculated according to Mc Gilchrist (1965) equation as follows:

1. For combination of 50:50 and 100:100, they were calculated according to the following equations:

$$Arc = Lr - Lc \;,\quad Acr = Lc - Lr$$

2. For the other combination ratios, the used equations were:

$$Aoc = \frac{Yrc}{Yrr \times Zrc} - \frac{Ycr}{Ycc \times Zcr}$$

$$Acr = \frac{Ycr}{Ycc \times Zcr} - \frac{Yrc}{Yrr \times Zrc}$$

Where:

Yrc = yield of roselle intercropped with cowpea, Ycr = yield of cowpea intercropped with roselle, Yrr = sole yield of roselle, Ycc = sole yield of cowpea, Zrc = sowing proportion of roselle and Zcr = sowing proportion of cowpea.

Statistical Analysis:

All collected data were subjected to analysis of variance and means of treatments were compared with the least significant difference (LSD) test at P≤0.05. The statistical calculations were performed with statistic software version 9 (Analytical Software, 2008).

Results

1. Land Equivalent Ratio (LER):

Total land productivity in terms of LER of relative dry sepals yield of roselle per feddan and relative seeds yield of cowpea per feddan as influenced by intercropping system, fertilization type and their combination treatments are recorded in Table 2. It can be observed that the means of all intercropping treatments were greater than one (LER > 1). This confirms the advantage of these types of intercropping to get more production from the same area of land as compared with the same unit of area in which sole crop is applied. Intercropping of roselle and cowpea at 2:3 and 1:2 were more productive than growing them separately or cropping them in 1:3 system since LER values were 1.252, 1.204, and 1.143 during first season and 1.233, 1.190, and 1.134 during second season, respectively. There was no significant difference between 2:3and 1:2 cropping systems. These LER values indicated that 20 to 25% and 19 to 23% more land would require planting the sole crops to produce the same quantities of intercrop yield of roselle and cowpea produced by using 1:2 and 2:3 during both seasons, respectively. In most cases there was significant difference between different biofertilization types and control (uninoculated plants). This means that using biofertilization had effect on LER value especially the use of *Azotobacter* treatment during both seasons. All combination treatments were more productive than sole crop (unit one).

Table 2: Effect of intercropping system and biofertilization type on land equivalent ratio (LER) during 2014 and 2015 seasons

Intercropping system (I) roselle:cowpea row ratio	Biofertilization type (B)									
	Without	A*	R**	A+R	Means (I)	Without	A	R	A+R	Means (I)
	2014 season					2015 season				
1: 1	1.108	1.199	1.176	1.193	1.169	1.101	1.191	1.131	1.175	1.150
1: 2	1.164	1.261	1.181	1.210	1.204	1.160	1.247	1.152	1.201	1.190
1: 3	1.145	1.165	1.155	1.143	1.152	1.163	1.140	1.113	1.119	1.134
2: 3	1.239	1.281	1.244	1.246	1.252	1.220	1.268	1.207	1.240	1.233
Means (B)	1.164	1.226	1.189	1.198		1.161	1.211	1.151	1.184	
LSD at 5 %	(I) = 0.020	(B) = 0.016		(I) (B) = 0.034		(I) = 0.017	(B) = 0.021		(I) (B) = 0.040	

A: *Azotobacter* R: *Rhizobium*

2. Area Time Equivalent Ratio (ATER):

Since land equivalent ratio does not take into account the time for which land is occupied by the component crops of an intercropping system, area time equivalent ratio was also determined. The

ATER provides more realistic comparison of the yield advantage of intercropping over that of sole cropping than land equivalent ratio as it considers variation in time taken by the two crops of different intercropping systems.

Yield advantage in terms of area time equivalent ratio (ATER) followed the similar trend recorded to LER (Table 3). All ATER values for intercropping systems were greater than unity except with 1: 3 system during the two seasons, thus demonstrating yield advantages for the intercropped systems compared to sole crop (Table 3). The highest ATER values were significantly recorded with 2:3 and 1:1 systems without significant difference between both of them during both seasons. On the other side, the lowest ATER value was produced with 1:3 system. Also, in most cases there was no significant difference between *Azotobacter* and a mixture of *Azotobacter* + *Rhizobium* which means that bioertilization types had effect on ATER value compared to uninoculted plants. Concerning the combination treatments, in most cases, combinations between intercropping system and biofertilization types produced lower ATER values (less than one unit) compared with sole crop system except when 2:3 system fertilized with *Azotobacter* in the two seasons. In all the treatments, ATER values were smaller than LER values (Table 3), indicating the over estimation of resource utilization in the latter. Thus contrary to LER, ATER is free from problems of over estimation of resource utilization.

Table 3: Effect of intercropping system and biofertilization type on area time equivalent ratio (ATER) during 2014 and 2015 seasons

Intercropping system (I) roselle:cowpea row ratio	Biofertilization type (B)									
	Without	A*	R**	A+R	Means (I)	Without	A	R	A+R	Means (I)
	2014 season					2015 season				
1: 1	0.976	1.058	1.034	1.055	1.031	0.976	1.056	0.997	1.042	1.018
1: 2	0.976	1.066	0.986	1.023	1.013	0.976	1.060	0.966	1.020	1.005
1: 3	0.944	0.964	0.948	0.952	0.952	0.961	0.945	0.916	0.934	0.939
2: 3	1.063	1.101	1.061	1.072	1.074	1.049	1.096	1.032	1.071	1.062
Means (B)	0.990	1.047	1.007	1.026		0.990	1.039	0.978	1.017	
LSD at 5 %	(I) = 0.017	(B) = 0.015		(I) (B) = 0.030		(I) = 0.016	(B) = 0.018		(I) (B) = 0.035	

A: *Azotobacter* R: *Rhizobium*

3. Land Utilization Efficiency Percentage (LUE%):

Main effect of intercropping system on land utilization effeciency suggest that there was no significant difference between roselle + cowpea (1:1) and (1:2) systems, while 2:3 system produced higher significant value of LUE% compared with the other systems under study during both seasons (Table 4). However, the lowest values of LUE% were achieved by using 1: 3 intercropping system in the two consecutive seasons. Also, main effect of biofertilization type revealed that all types gave LUE% values more than 100% with significant differences between different types during both seasons in most cases. Whenever, the best treatment in this regard was *Azotobacter* which followed by the treatment by a mixture (*Azotobacter* + *Rhizobium*) in the first and second seasons.

Table 4: Effect of intercropping system and biofertilization type on land utilization efficiency percentage (LUE%) during 2014 and 2015 seasons

Intercropping system (I) roselle:cowpea row ratio	Biofertilization type (B)									
	Without	A*	R**	A+R	Means (I)	Without	A	R	A+R	Means (I)
	2014 season					2015 season				
1: 1	104.23	112.85	110.52	112.39	110.00	103.86	112.36	106.41	110.86	108.37
1: 2	107.01	116.34	108.37	111.66	110.84	106.81	115.35	105.92	111.02	109.77
1: 3	104.50	106.45	105.15	104.74	105.21	106.19	104.26	101.45	102.67	103.64
2: 3	115.09	119.09	115.26	115.90	116.33	113.44	118.18	111.91	115.54	114.77
Means (B)	107.71	113.68	109.82	111.17		107.57	112.54	106.42	110.02	
LSD at 5 %	(I) = 1.821	(B) = 1.531		(I) (B) = 3.207		(I) = 1.659	(B) = 1.918		(I) (B) = 3.706	

A: *Azotobacter* R: *Rhizobium*

As shown in Table 4, all interactions between intercropping systems and biofertilization types gave LUE% values more than 100% during first season except when the intercropping system of Roselle + guar (2: 4) was applied without nitrogen fertilization. However, the interaction treatment between intercropping system of two rows of roselle + three rows of cowpea (2:3 system) and *Azotobacter* type of biofertilization was superior in this respect compared to the other ones under study in the first and second seasons.

4. Aggressivity:

Aggressivity measures the interspecies competition in intercropping by relating the yield changes of both component crops (McGilchrist, 1965). This index compares the yields between intercropping and sole crop, as well as their respective land occupancy (Li *et al*., 2001; Williams and McCarthy, 2001; Zhang and Li, 2003; Wahla *et al*., 2009).

It is known that an aggressivity value of zero indicates that the intercropping crops are equally competitive. For any other situation, two crops will have the same numerical value by positive for the dominant crop and negative for the dominated crop.

Data presented in Table 5 show that the competitive ability of the two component crops in an intercropping system is determined by its aggressivity value. Regardless of the planting systems, there was a positive sign for roselle and a negative sign for the intercropped cowpea, indicating that roselle was dominant while cowpea was dominated. Results showed the highest positive aggressivity for roselle at 1:3 system, while it proved less competitive at 1:1 planting system during both seasons. Also, the combination treatment between 1:3 or 1:2 systems and a mixture (*Azotobacter* + *Rhizobium*) of biofertilization gave the highest values in this connection in the first and second season, respectively.

Table 5: Effect of intercropping system and biofertilization type on aggressivity values (A) of roselle (Arc) and cowpea (Acr) during 2014 and 2015 seasons

Intercropping system (I) roselle:cowpea row ratio	Biofertilization type (B)									
	Without	A*	R**	A+R	Means (I)	Without	A	R	A+R	Means (I)
	Aggressivity values of roselle (Arc)									
	2014 season					2014 season				
1: 1	0.053	0.080	0.040	0.087	0.065	0.101	0.112	0.064	0.109	0.096
1: 2	0.113	0.277	0.030	0.273	0.173	0.160	0.366	0.107	0.540	0.293
1: 3	0.290	0.367	0.207	0.510	0.343	0.330	0.403	0.248	0.533	0.379
2: 3	0.167	0.197	0.053	0.223	0.160	0.213	0.314	0.099	0.303	0.232
Means (B)	0.156	0.230	0.082	0.273		0.201	0.299	0.129	0.371	
LSD at 5 %	(I) = 0.017		(B) = 0.045	(I) (B) = 0.080		(I) = 0.092	(B) = 0.097		(I) (B) = 0.191	
	Aggressivity values of cowpea (Acr)									
	2015 season					2015 season				
1: 1	-0.053	-0.080	-0.040	-0.087	-0.065	-0.101	-0.112	-0.064	-0.109	-0.096
1: 2	-0.113	-0.277	-0.030	-0.273	-0.173	-0.160	-0.366	-0.107	-0.540	-0.293
1: 3	-0.290	-0.367	-0.207	-0.510	-0.343	-0.330	-0.403	-0.248	-0.533	-0.379
2: 3	-0.167	-0.197	-0.053	-0.223	-0.160	-0.213	-0.314	-0.099	-0.303	-0.232
Means (B)	-0.156	-0.230	-0.082	-0.273		-0.201	-0.299	-0.129	-0.371	
LSD at 5 %	(I) = 0.017		(B) = 0.045	(I) (B) = 0.080		(I) = 0.092	(B) = 0.097		(I) (B) = 0.191	

A: *Azotobacter*   R: *Rhizobium*

Discussion

The above mentioned results clearly signifying the superiority of intercropping over sole crop of either of the two crops; *i.e.*, roselle or cowpea since all intercropping systems produced LER and ATER values more than unit in most cases. Also, LUE values were more than 100% with all applied intercropping systems during the two seasons. Intercropping of roselle and cowpea at 2:3 and 1:2 systems were more promising than sole crop or 1: 1 and 1: 3 systems since the total yield of both crops increased by 20-25 % and 19-23 % compared with sole crop during both seasons, respectively.

The enhancing effect of intercropping on land utilization efficiency indices was previously reported by Rajeswara Rao (2002), John and Mini (2005), Marer *et al*. (2007), Rahman *et al*. (2009), Abdelkader and Hamad (2015) and Abdelkader and Mohsen (2016). This advantage is probably due to different above- and below-ground growth habits and morphological characteristics of intercrop components causing a greater efficiency in the using of plant growth resources, i.e. water, nutrients and radiation energy (Willey, 1979; Ofori and Stern, 1987 and Fukai and Trenbath, 1993).

Analysis of variance demonstrates that biofertilization types had significant effect on LER, ATER and LUE values. However, all types surpassed the unit. A similar result was reported by Ghaley *et al*. (2005), Dariush *et al*. (2006), Li *et al*. (2009) and Mohammed *et al.* (2016).

The maximum values of LER, ATER and LUE were recorded when roselle and cowpea were intercropped in 2:3 system and fertilized with *Azotobacter* which considered the best system to be followed.

The above mentioned data showed that the component crops did not exhibit equal competitive intensity based on aggressivity (Tables 5). The aggressivity index of roselle relative to cowpea was positive which indicating that roselle was the dominant species and had much greater competitiveness in the intercropping system of roselle with cowpea. In general, earlier studies demonstrated that non-legume crop is considered a suppressing crop in annual legume/non-legume intercrop system (Haynes, 1980 and Wahla *et al*., 2009), for examples soybean/wheat (Li *et al*., 2001), peanut/maize (Inal *et al*., 2007), faba bean/barley (Strydhorst *et al*., 2008) and cowpea/okra (Zyada, 2016). This reveals that roselle intercropped with cowpea utilized the resources more aggressively, and its production was the major factor that determined the overall yields.

Recommendation

This study suggests that roselle/cowpea association can be used by farmers instead of roselle sole crop, especially at 2:3 cropping system, under Sharkia Governorate conditions. Use of the *Azotobacter* inoculation for cowpea, in the intercropping pattern of 2:3, enhanced roselle and cowpea productivity and maximized land equivalent ratio as well as land utilization efficiency.

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