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Intercropping Faba bean with Some Crops and Its Impact on the Production, Phyllosphere and Rhizosphere Microorganisms Under Modern Irrigation Systems

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Abstract

Two field experiments were carried out at Arab El-Awammer Research Station, Assiut Governorate, Agricultural Research Centre, during 2016-2017 and 2017-2018 seasons. The present study assessed the effect of intercropping faba bean with some crops on the production, phyllosphere and rhizosphere microorganisms under modern irrigation systems. Two separates experiments were done and each experiment was subjected to one of studied irrigation systems (sprinkler and drip irrigations). Each experiment contained seven treatments of cropping systems (sole faba bean, sole onion, sole garlic, sole fennel, faba bean + onion, faba bean + garlic and faba bean + fennel). Results showed that plant height, number of branches/plant, number of pods/plant, seed yield/plant, weight of 100 seed and seed yield/fed of faba bean was decreased when intercropped with onion, garlic and fennel compared with sole faba bean in the both seasons. Drip irrigation produced the maximum yield and its attributes of faba bean as compared with sprinkler irrigation in the both seasons. Sole onion and garlic gave the highest values of yield/fed under drip irrigation as compared with intercrop with faba bean and sprinkler irrigation in the both seasons. However, fennel intercrop with faba bean produced the highest value of yield/fed under sprinkler irrigation as compared with sole fennel and drip irrigation in the both seasons. The highest value of land equivalent ratio (LER) 1.92 was observed when fennel intercrop with faba bean under sprinkler irrigation in the second season. Competitive ratio (CR) values of onion, garlic and fennel intercrop with faba bean were greater than of sole faba bean in the both seasons. The highest value of monetary advantage index (MAI) 6519.96 was observed when intercropping faba bean with garlic under drip irrigation in the second season. Rhizosphere and phyllosphere microorganisms were highly affected by the intercropping and various irrigation systems. Total counts of both bacteria and fungi in plants phyllosphere were high under sprinkle irrigation than under drip irrigation system while, in drip irrigation was highest in rhizosphere. Sole cropping contained higher microbial number than cropping system. Higher values of the biodiversity index indicate large variation in fungal communities of different plants especially in intercropping.

Keywords: *faba bean, fennel, sprinkler, drip irrigation, phyllosphere, microorganisms.*

Introduction

Intercropping is a type of mixed cropping and defined as agricultural practice of cultivating two or more

crops in the same space at the same time. In cropping system, all the environmental resources utilized to maximize crop production per unit area and per unit time. Thus, cropping systems have several benefits to the farmers such as, flexibility, profit maximization, risk minimization against total crop failure or disease, weed control, increase land use efficiency, soil conservation, improvement of soil fertility by the use of legumes, enhancing the capture and use of light and water (Hamd Alla *et al.* 2014; Dhima *et al.* 2007). Yield and yield attributes of the three crops (faba bean, onion and wheat) were decreased under intercropping condition, the most yield attributes of intercropped faba bean (number of branches/plant and seed yield/plant) were decreased which resulted in decreased seed yield/fed. the yield and yield attributes of intercropped crops (onion and wheat) were decreased when intercropping with faba bean, The highest values of land equivalent ratio (1.59) and the values of competitive ratio of faba bean were greater when intercropping on onion (Abou-Keriasha *et al.* 2013). Intercropping can improve the use of resources (land, nutrients, especially soil nitrogen, light, water) by 10–50 % above sole crop grown on the same piece of land expressed in land equivalent ratio (Willey 1979). The advantages of intercropping are derived from the competitive interference principle (Vandermeer 1989), in which the interspecific competition between intercrop component species will be less than intraspecific competition in sole crops. Yield advantages have been recorded in many legume-cereal cropping systems, included soybean-sorghum (Ghosh *et al.,* 2009). (Liben *et al.* 2001; Eskandari and Ghanbari 2010) the highest land equivalent ratio and economic advantage with a net return were observed in treatment one row maize:one row faba bean. (Abdel-Zaher *et al.* 2009) reported that competition ratio fahl berseem was always more competitive than wheat. In Egypt, intercropping faba bean on other winter crops (wheat, onion, garlic, fennel, sugar beet, sugar cane and tomato) is assistant in increasing the cultivated faba bean area and reducing the gap between production and consumption.

Microbial communities, particularly fungi and bacteria form a characteristic component in all biological ecosystems (Swer *et al.* 2011). They play a critical role in terrestrial ecosystems as major plant residues decomposers; resulting nutrients stimulate other plant growth (Carlile *et al.* 2001); produced wide range of biological compounds, e.g. antibiotics, enzymes, pigments, vitamins, organic acids, and other pharmaceuticals materials (Sette *et al.* 2013). The presence of these microorganisms keeps the ecological balance of different environmental habitats. Rhizosphere identified as the soil portion under the direct influence of the plant roots. This portion supports large and active microbial population capable of exerting beneficial compounds; also plant-microbe interactions in the rhizosphere are responsible for increasing both plant health and soil fertility (Ahmad *et al.* 2008; Sule and Oyeyiola 2012). Phyllosphere represented another important plant habitat that contains a wide range of micro-

organisms (Lindow and Brandl, 2003). It's considered a suitable environment for microbial growth because of a thin film of nutrients deposited on the leaves (Prabakaran *et al.* 2011). Microbial communities reach the phyllosphere by atmospheric deposition from different sources, e.g., plant, soil and human activities as well as to the behavior of the individual plants on which they live (Wilson *et al.* 1999; Morris *et al.* 2002). Microbial communities here influenced by external and/or internal factors such as nutrient availability, humidity, temperature, leaf age and type, and presence of inhibitors (chemical compounds produced by the plant) (Santamaria and Bayman 2005; Evueh and Ogbebor 2008).

Therefore, the objective of this study was to assess the effect of intercropping faba bean with some crops on the productivity and microbial evaluation under modern irrigation systems.

Materials and Methods

Experiments site

The current study was conducted at Arab El-Awammer Research Station, Assiut Governorate, Agricultural Research Centre, during 2016-2017 and 2017-2018 seasons. The field site was located between latitude 27° 05′ and longitude 31° 64′.

Selected plants

Four different crops were selected including faba bean (*Vicia faba* L.), onion (*Allium cepa* L.), garlic (*Allium sativuml* L.) and fennel (*Foeniculum vulgare* Mill). The preceding crop was sorghum in both seasons. The experiments were conducted on sandy calcareous soil consisting of sandy 89.9%, silt 7.1%, clay 3 %, pH 8.37, $CaCO_3$ (%) 35.18, EC 0.35 dSm^{-1}, total nitrogen (%) 0.003, available phosphorus 8.31 ppm and organic matter 0.19%.

Experiments design

Two separate experiments were laid out and each experiment was subjected to one of studied irrigation systems (sprinkler and drip irrigation). Each experiment was contained seven treatments of cropping systems (sole faba bean, sole onion, sole garlic, sole fennel, faba bean + onion, faba bean + garlic and faba bean + fennel). Sole faba bean seeds were drilled in both sides of ridge (60 cm width), with two plants/hill and 20 cm between hills. Sole onion plants were transplanted in two side of ridge (60 cm width), spaced at 10 cm between transplants. Sole garlic seeds were drilled in both sides of ridge (60 cm width), spaced at 10 cm between hills. Sole fennel grew in one side of ridge (60 cm width), with two plants/hill and 25 cm between hills. faba bean + onion, faba bean + garlic and faba bean + fennel (intercrop): faba bean was sown in one side of ridge, while onion, garlic and fennel were sown in another side of the same ridge. Each experiment was laid out using a randomized complete block design with three replications. The plot size was 7.5 m^2 (2.5 m long×3 m wide) contained five rows. faba bean seeds cultivar Giza 843, onion cultivar Giza 6 mohassan, garlic cv. local cultivar and fennel cv. local cultivar. Faba bean, garlic and fennel were sown on October 16th and 20th in 2016 and 2017 seasons, respectively. Meanwhile, onion was sown on November 19th and 22th in 2016 and 2017seasons, respectively.

Faba bean, onion, garlic and fennel were fertilized with 200 kg/fed. of calcium super phosphate (15.5% P_2O_5) during land preparation and potassium sulphate (48.8% K_2O) at the rate of 50 kg/fed which was applied in two equal doses. Nitrogen fertilizer was added at the rate of 30, 150, 150 and 75 kg N fed^{-1}, for faba bean, onion, garlic and fennel, respectively, in the form of ammonium nitrate (33.5%) in six equal doses under intercropping and sole crops. Cultural management disease and pest control programs for faba bean, onion, garlic and fennel crops were followed as recommended by the Egyptian Ministry of Agriculture.

Actual applied irrigation water

The amounts of actual applied irrigation water under drip and sprinkler irrigation systems were determined according to James (1988) using the following equation:

$$I.Ra = \frac{ETc + Lf}{Er} \quad (1)$$

Where:

I.Ra = total actual irrigation water applied mm/ interval.

ETc = Crop evapotranspiration with using FAO Penman- Monteith equation

Lf = leaching factor 10 %.

Er = irrigation system efficiency.

Crop yields determination

Faba bean traits

At harvest, ten guarded plants of faba bean from each experimental unit were taken randomly to determine plant height (cm), number of branches/plant, number of pods/plant, seeds yield/plant, weight of 100 seed (g) and all harvested plants from each experimental unit were used to determine the seed yield (kg/fed).

Onion, garlic and fennel traits

All harvested plants from each experimental unit were used to determine the yield (ton/fed).

Competitive relationships

Land equivalent ratio (LER); defined as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield (Willey, 1979). It was calculated as follows:

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba} / Y_{bb}) \quad (2)$$

Where Y_{aa} = Pure stand yield of crop (a); Y_{bb} = Pure stand yield of crop (b); Y_{ab} = Intercrop yield of crop a and Y_{ba} = Intercrop yield of crop b.

Competitive ratio (CR); indicates the number of times by which one component crop is more competitive than the other. Relative species competition is often evaluated using competitive ratios (Willey and Rao, 1980). It was calculated as follows:

$$R_a = (L_a / L_b) \times (Z_{ba} / Z_{ab})$$
$$R_b = (L_b / L_a) \times (Z_{ab} / Z_{ba}) \quad (3)$$

Where R_a = The competitive ratio of crop a; R_b = The competitive ratio of crop b; L_a = LER of crop a; L_b = LER of crop b; Z_{ab} = The respective proportion of crop a in the cropping system and Z_{ba} = The respective proportion of crop b in the cropping system.

Monetary advantage index (MAI); Suggests that the economic assessment should be terms of the value of land saved; this could probably be most assessed on the basis of the rentable value of this land. MAI was calculated according to the formula, as suggested by (Willey, 1979).

$$MAI = \frac{\text{Value of combined intercrops} \times LER - 1}{LER} \quad (4)$$

In Egyptian pound faba bean price was 9.16 L.E./kg, onion was 1053 L.E./ton, garlic was 2789

L.E./ton and fennel was 6732 L.E./ton of the two seasons (Bulletin of Agriculture Statistical Cost Production and Net Return, 2017).

Microbiological assay

Media used for microbial isolation

Nutrient agar medium (NA) used for total viable bacterial counts containing (g/l) beef extract, 10.0; peptone, 10.0; NaCl, 5.0; agar, 15.0; distilled water, 1000 ml and intial pH 6.8 (Atlas, 1993). For nitrogen fixing bacteria; nitrogen free medium was used (Becking, 2006) containing 1.0g K_2HPO_4,0.1g $CaCl_2$. $2H_2O$,0.2g $MgSO_4.7H_2O$,0.05g $FeSO_4.7H_2O$, 0.005g $Na_2MoO_4.2H_2O$, Sucrose 10.0g 1000 ml distilled water). For fungal isolation; potato dextrose agar medium (PDA) was used containing (g/l): potato (scrubbed and diced), 200; dextrose, 15.0 and agar, 20.0; distilled water, 1000 ml and initial pH 5.6. The medium was supplemented with rose-bengal and Chloramphenicol as bacteriostatic and bactericidal agents, respectively (Smith and Dawson, 1944). For preparation of the medium, potato was boiled for 1h and passes the mixture through a fine sieve (cloth chess), add dextrose, stir, add agar and boil until dissolving then autoclaved at 121ºC for 20 min. (Booth, 1971).

Isolation and identification of microorganisms

Plants were uprooted randomly for rhizosphere and phyllosphere microbial determination according to Abdel-Hafez *et al.* (1990), for rhizosphere; plant roots gently shaken to obtain the rhizosphere superfluous soil, for phyllosphere sampling; leaves were randomly collected from different plants in the area under study. All samples directly placed in clean and sterilized polyethylene bags and transferred to laboratory for microbial determination. A known weight of rhizosphere soil or fresh leaves was immersed in flask containing sterilized distilled water. After shaken, suitable dilutions were prepared. One ml of the rhizosphere or phyllosphere soil suspension was transferred to each sterilized Petridish and covered with sterilized melted and cooled medium. The plates were incubated at 30 ±1ºC for 48 h. for bacterial isolation and at 28 ±1ºC for 7 days for fungi isolation. The counts were calculated as colony forming units (CFU) per g of rhizosphere soil or fresh leaves. Taxonomic identification of fungal isolates was mainly based on the following morphological identification keys: Pitt (1980) for *Penicillium*; Raper and Fennell (1965) for *Aspergillus*; Booth (1971) for *Fusarium*; Ellis (1976) for dematiaceous hyphomycetes and Anisworth & Bisby's Dictionary of the fungi (Kirk *et al.* 2001).

Diversity analysis of fungi

Species richness index (S) calculated according to Jiang *et al.* (2016) by counting the number of fungal species in each treatment. Shannon–Wiener index (H') and Simpson's diversity index (D_s) were calculated by the equations (5) & (6), respectively, species evenness evaluated by Pielou's evenness index (J) was calculated by equation (7) as described by Bråthen *et al.* (2015).

$$H' = -\sum_{i=1}^{s} P_i \ln P_{i,} \quad Pi = Ni / Nt \qquad (5)$$

$$D_s = 1 - \sum_{i=1}^{s} P_i^2 \qquad (6)$$

$$J = H / H_{max}, \; H_{max} = \ln S \qquad (7)$$

Where Ni; is the species isolates number, Nt; is the total fungal num-

ber of each treatment and S; is the total species number in each treatment.

Statistical analysis:

Data were analyzed by MSTAT-C (1991) software package. Separate analysis of variance using randomized complete block design (RCBD) was carried out for each irrigation system according to Gomez and Gomez (1984). Means were compared by Least Significant Difference (LSD) at 5% level of significant.

Results and Discussion

1- Sprinkler irrigation:

Effect of cropping system on yield and its attributes of faba bean.

Data presented in Table 1 revealed that cropping systems had a significant effect on all studied traits except number of pods/plant and seed yield/plant in the first season. Data indicated that the plant height, number of branches/plant, number of pods/plant, seed yield/plant, weight of 100 seed and seed yield/fed. of faba bean was decreased when intercropped with onion, garlic and fennel compared with sole faba bean in the both seasons. The decrease was due to the severe interspecific competition between faba bean and other crops plants for light, water and nutrients. These findings are in harmony with those obtained by Willey (1979), Vandermeer (1989), Abou-Keriasha *et al.* (2013) and Hamd Alla *et al.* (2014).

Table 1. Effect of cropping system on yield and its attributes of faba bean during 2016-2017 and 2017-2018 seasons.

Cropping system	Plant height (cm)	No. of branches /plant	No. of pods/ plant	Seed yield/plant (g)	Wt. of 100 seed (g)	Seed yield (kg/fed)
2016-2017						
Sole faba bean	99.10	3.27	18.67	17.42	58.52	521.60
Faba bean + onion	97.77	2.73	15.33	15.05	57.44	258.57
Faba bean + garlic	97.53	2.20	14.33	14.88	57.18	223.31
Faba bean + fennel	96.23	1.97	12.00	13.06	56.03	218.90
F Test	**	**	NS	NS	*	**
L.S.D 0.05	0.36	0.34	-	-	1.63	54.90
2017-2018						
Sole faba bean	100.73	3.30	20.10	17.40	58.93	565.27
Faba bean + onion	98.75	2.87	17.30	16.06	57.84	396.04
Faba bean + garlic	98.20	2.37	16.53	15.18	57.62	330.81
Faba bean + fennel	97.33	2.07	13.53	13.30	57.15	273.59
F Test	**	**	**	**	*	**
L.S.D 0.05	1.01	0.52	1.42	0.76	1.10	66.22

NS, * and ** means not significant, significant at 0.05 and 0.01 probability, respectively.

Effect of cropping systems on yield of intercrops onion, garlic and fennel with faba bean.

Exhibited data in Table 2 showed that sole onion and garlic had the highest values of yield as compared with intercrop with faba bean in the both season. However, fennel intercrop with faba had the highest value of yield as compared with sole fennel in the both seasons. Similar finding was reported by Abou-Keriasha *et al.* (2013).

Table 2. Effect of cropping systems on yield of intercrops onion, garlic and fennel with faba bean during 2016-2017 and 2017-2018 seasons.

Onion		Garlic		Fennel	
Yield (ton/fed)					
Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
2016-2017					
12.15	6.75	11.02	7.56	0.495	0.685
2017-2018					
12.67	7.93	11.41	8.15	0.510	0.732

Applied irrigation water (m^3/fed) as affected by cropping systems.

The results in Table 3 indicated that the applied irrigation amount to sole faba bean under sprinkler irrigation was as the same as the amount applied to each of the three cropping systems. Thus, in these cropping systems, three crops (faba bean and onion, garlic or fennel) used the applied irrigation water to faba bean, which imply saving in the applied irrigation water. This result was true in the both growing seasons. Furthermore, the applied irrigation amount to sole faba bean was the highest and the applied irrigation water to sole onion was the lowest. This result could be attributed to larger above ground biomass of faba bean, compared to smaller above ground biomass of onion. The results also indicated that the amounts of applied irrigation water to all the studied cropping systems were higher in the second growing season, compared to the first growing season, may be due to higher temperature in the second growing seasons, compared to the first growing season.

Table 3. Applied irrigation water (m^3/fed) as affected by cropping system during 2016-2017 and 2017-2018 seasons.

Cropping system	2016-2017	2017-2018
Faba bean + onion	2026.2	2279.3
Faba bean + garlic	2026.2	2279.3
Faba bean + fennel	2026.2	2279.3
Sole faba bean	2026.2	2279.3
Sole onion	1817.8	2139.3
Sole garlic	1985.1	2226.0
Sole fennel	1829.1	2078.2

Effect of faba bean with onion, garlic and fennel intercropping on competitive relationships.

Land equivalent ratio (LER); the presented data in Table 4 land equivalent ratio (LER) values were greater than one, in the both seasons. Here, it could be concluded that actual productivity was higher than the expected productivity. The highest LER value of 1.92 was observed when fennel intercrop with faba bean in the second season, while the lowest value of 1.05 was observed onion intercrop with faba bean in the first season. The results of current study are in harmony with those recorded by Willey (1979), Liben *et al.* (2001), Eskandari and Ghanbari 2010 (2010) and Abou-Keriasha *et al.* (2013).

Competitive ratio (CR); which expresses the exact degree of competitively. The illustrated data in Table 4 revealed that values of onion, garlic and fennel intercrop with faba bean were greater than of sole faba bean in both seasons. This is indicating that dominance of onion, garlic and fennel on faba bean. These findings are in harmony with those obtained by Abdel-Zaher *et al.* (2009).

Monetary advantage index (MAI); is considered an indicator of the economic feasibility of cropping systems, results presented in Table 4 indicated that the highest MAI values of 3562.08 and 5946.03 were obtained from faba bean + fennal and faba bean + garlic in the second season, respectively. These MAI values were positive due to LER which were greater than one. These results are agreement with those obtained by Abou-Keriasha *et al.* (2012) and Hamd Alla *et al.* (2014) who's stated that economic benefit expressed with the higher MAI values in intercropping.

Table 4. Effect of cropping system on land equivalent ratio (LER), competitive ratio (CR) and monetary advantage index (MAI) during 2016-2017 and 2017-2018 seasons.

Cropping system	Land equivalent ratio (LER)						Competitive ratio (CR)				Monetary advantage index (MAI)	
	2016-2017			2017-2018			2016-2017		2017-2018			
	Faba bean	Intercrop	LER	Faba bean	Intercrop	LER	Faba bean	Intercrop	Faba bean	Intercrop	2016-2017	2017-2018
Faba bean + onion	0.49	0.56	1.05	0.70	0.63	1.33	0.89	1.13	1.11	0.90	450.60	2972.77
Faba bean + garlic	0.42	0.69	1.11	0.59	0.71	1.30	0.62	1.61	0.82	1.21	2293.03	5946.03
Faba bean + fennel	0.42	1.38	1.80	0.48	1.44	1.92	0.61	1.64	0.67	1.49	2940.69	3562.08

2- Drip Irrigation:

Effect of cropping system on yield and its attributes of faba bean.

The data reported in Table 5 revealed that cropping systems had a significant effect on all studied traits. the results declared that the plant height, number of branches/plant, number of pods/plant, seed yield/plant, weight of 100 seed and seed yield/fed. of faba bean was decreased when intercropped with onion, garlic and fennel compared with sole faba bean in the both seasons. Those results may be due to competition of associated crops for intercepted the light intensity compared with sole faba bean. Similar findings were reported by Willey (1979), Vandermeer (1989), Abou-Keriasha *et al.* (2013) and Hamd Alla *et al.* (2014).

Effect of cropping systems on yield of intercrops onion, garlic and fennel with faba bean.

The obtained data in Table 6 indicated that sole onion and garlic had the highest values of yield as compared with intercrop with faba bean in the both season. However, fennel intercrop with faba had the highest value of yield as compared with sole fennel in the both seasons. The same trend was detected by Abou-Keriasha *et al.* (2013).

Applied irrigation water (m^3/fed) as affected by cropping systems.

The results presented in Table 7 revealed that results were obtained under drip system similar to sprinkler irrigation, where the applied irrigation water to each of the studied cropping systems were similar to the applied amount to sole faba bean in both growing seasons. The highest amount of irrigation water was applied to faba bean, whereas the lowest amount was applied to onion.

Table 5. Effect of cropping system on yield and its attributes of faba bean during 2016-2017 and 2017-2018 seasons.

Cropping system	Plant height (cm)	No. of branches /plant	No. of pods/ plant	Seed yield/plant (g)	Wt. of 100 seed (g)	Seed yield (kg/fed)
2016-2017						
Sole faba bean	100.47	4.13	20.00	17.90	60.25	576.04
Faba bean + onion	98.43	3.23	16.67	15.87	58.58	328.91
Faba bean + garlic	98.17	2.70	15.00	14.98	58.29	307.48
Faba bean + fennel	96.80	2.43	13.33	13.86	57.84	283.95
F Test	**	*	**	**	**	**
L.S.D 0.05	1.19	0.85	2.42	1.74	1.08	25.72
2017-2018						
Sole faba bean	101.67	4.43	21.67	19.67	59.99	600.87
Faba bean + onion	99.27	3.47	18.60	18.84	58.94	438.27
Faba bean + garlic	98.72	2.87	17.57	17.70	58.78	372.01
Faba bean + fennel	98.10	2.67	14.60	15.71	57.98	314.50
F Test	**	*	**	**	**	**
L.S.D 0.05	1.01	1.04	1.63	1.54	0.86	54.76

* and ** means significant at 0.05 and 0.01 probability, respectively.

Table 6. Effect of cropping systems on yield of intercrops onion, garlic and fennel with faba bean during 2016-2017 and 2017-2018 seasons.

Onion		Garlic		Fennel	
Yield (ton/fed)					
Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
2016-2017					
13.63	7.67	11.33	8.13	0.420	0.447
2017-2018					
14.10	9.13	11.52	8.20	0.473	0.582

Table 7. Applied irrigation water (m^3/fed) as affected by cropping system during 2016- 2017 and 2017-2018 seasons.

Cropping system	2016-2017	2017-2018
Faba bean + onion	1787.8	2011.2
Faba bean + garlic	1787.8	2011.2
Faba bean + fennel	1787.8	2011.2
Sole faba bean	1787.8	2011.2
Sole onion	1604.0	1887.6
Sole garlic	1751.5	1964.1
Sole fennel	1613.9	1833.7

Effect of faba bean with onion, garlic and fennel intercropping on competitive relationships.

Land equivalent ratio (LER); data in Table 8 showed that land equivalent ratio (LER) values were greater than one, in both seasons. Here, it could be concluded that actual productivity was higher than the expected productivity. The highest LER value of 1.75 was observed when fennel intercrop with faba bean in the second season, while the lowest value of 1.13 was observed onion intercrop with faba bean in the first season. Similar results in this respect were observed by of Willey (1979), Liben *et al.* (2001), Eskandari and Ghanbari 2010 (2010) and Abou-Keriasha *et al.* (2013).

Competitive ratio (CR); which expresses the exact degree of competitively. The obtained data in Table 8 explained that values of onion, garlic and fennel intercrop with faba bean were greater than of sole faba bean in both seasons. This is indicating that dominance of onion, garlic and fennel on faba bean. General agreements in this respect were declared by Abdel-Zaher *et al.* (2009).

Monetary advantage index (MAI); is considered an indicator of the economic feasibility of cropping systems, results recorded in Table 8 showed that the highest MAI values of 5099.89 and 6519.96 were obtained from faba bean + garlic in the first and second seasons, respectively. These MAI values were positive due to LER which were greater than one. The previous results are in same line with those obtained by Abou-Keriasha *et al.* (2012) and Hamd Alla *et al.* (2014) who's stated that economic benefit expressed with the higher MAI values in intercropping.

Table 8. Effect of cropping system on land equivalent ratio (LER), competitive ratio (CR) and monetary advantage index (MAI) during 2016-2017 and 2017-2018 seasons.

Cropping system	Land equivalent ratio (LER)						Competitive ratio (CR)				Monetary advantage index (MAI)	
	2016-2017			2017-2018			2016-2017		2017-2018			
	Faba bean	Intercrop	LER	Faba bean	Intercrop	LER	Faba bean	Intercrop	Faba bean	Intercrop	2016-2017	2017-2018
Faba bean + onion	0.57	0.56	1.13	0.73	0.65	1.38	1.02	0.98	1.12	0.89	1276.13	3753.63
Faba bean + garlic	0.53	0.72	1.25	0.62	0.71	1.33	0.74	1.35	0.87	1.15	5099.89	6519.96
Faba bean + fennel	0.49	1.06	1.55	0.52	1.23	1.75	1.08	1.08	0.85	1.17	2013.91	2913.79

Effect of irrigation system and cropping systems on bacterial counts

Data in Figures 1&2 cleared high variation between bacterial counts isolated under different irrigation system and intercropping during the two seasons. We clearly observed that, the total bacterial counts (including general and nitrogen fixing) in phyllosphere were higher in sprinkle irrigation than drip irrigation while in rhizosphere were higher in drip irrigation than sprinkle irrigation. Rhizosphere and phyllosphere bacteria have huge agricultural and environmental importance by their ability to affect plant growth (Rasche *et al.* 2006) and suppress or stimulate the plant pathogens colonization of different plant tissues (Lindow and Brandl, 2003). Total rhizosphere bacteria counts were higher under drip irrigation than sprinkle irrigation system, also nitrogen fixing bacteria showed great affect with intercropping by increasing its number in sole plants than intercropping ones however general bacterial counts (non-nitrogen fixing) have opposite affect by increasing sharply in intercropping plants. Highest rhizosphere bacterial count was in sole onion plants (50×10^7 CFU/g soil) under drip irrigation system while the lowest rhizosphere bacterial count was 5×10^7 CFU/g soil in sole fennel under drip irrigation. Phyllosphere bacteria counts was higher under sprinkle irrigation than drip irrigation system, also nitrogen fixing recorded in high number in sole cropping than cropping system. Highest phyllosphere bacterial count was in sole onion plants (43×10^6 CFU/g leaves) under sprinkle irrigation system. Mercier and Lindow (2000) observed that leaf surface is exposed every day to rapidly fluctuating temperature changes and relative humidity, which consequently affect the microbial presence and counts on the leaf. According to Hirano and Upper (2000) leave colonized bacteria containing between 10^6-10^7 cells/cm^2 of leaf.

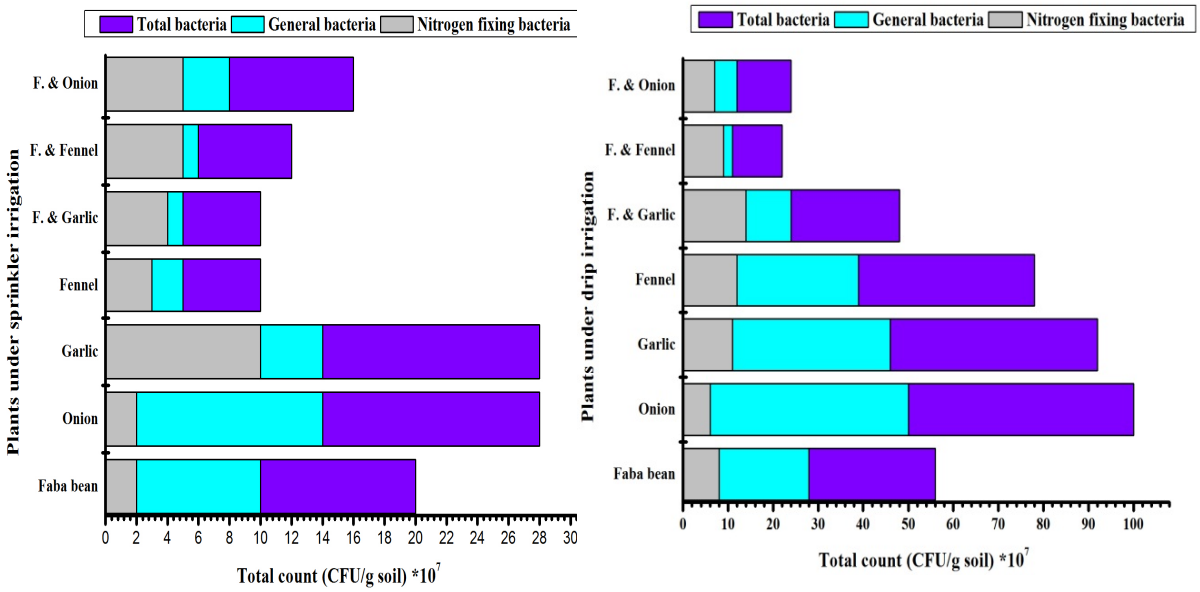

Figure 1. Bacterial counts in rhizosphere (CFU/g soil) under sprinkler and drip irrigation during the two seasons.

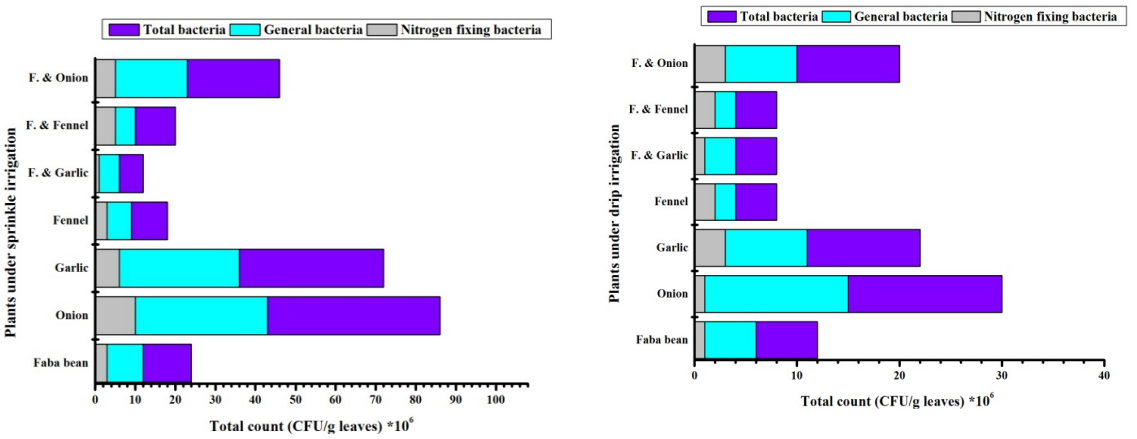

Figure 2. Bacterial counts in phyllosphere (CFU/g leaves) under sprinkler and drip irrigation during the two seasons.

Effect of irrigation system and cropping systems on fungal counts and diversity

Data in Figure 3 revealed that fungi also take the same direction of bacteria concerning its total counts under different irrigation systems and intercropping during the two seasons. Fungal total counts in phyllosphere was high in sprinkle irrigation than drip irrigation system while in rhizosphere was high in drip irrigation than sprinkle irrigation system. Highest rhizosphere fungal count was in sole fennel plants (46×10^3 CFU/g soil) under drip irrigation system while the lowest rhizosphere fungal count was 7×10^3 CFU/g soil in sole garlic under sprinkle irrigation**.** Highest phyllosphere fungal count was in sole onion plants (24×10^3 CFU/g leaves) under sprinkle irrigation system while the lowest phyllosphere fungal count was 9×10^3 CFU/g leaves in sole faba bean & garlic under drip irrigation.

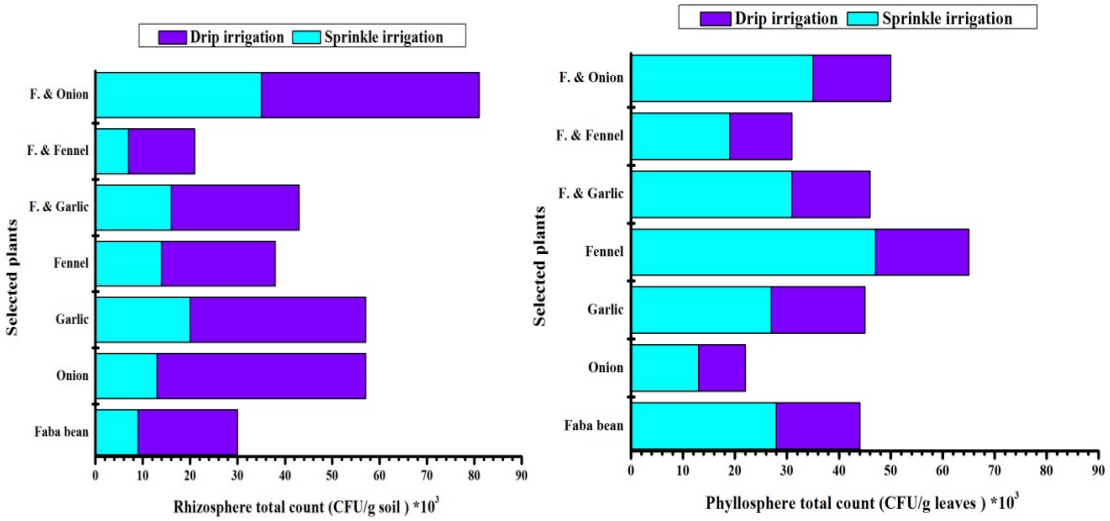

Figure 3. Fungal total counts under sprinkler and drip irrigation systems during the two seasons.

During this investigation twenty fungal species and one variety belonging to twelve genera were recovered. Remarkably, *Emericella nidulans* var. *nidulans* (Eidam) Vuillemin, *Fusarium culmorum* (W.G. Smith) Saccardo and *F. lateritium* Nees recovered only from intercropping plants in rhizosphere; while *Alternaria chlamydospora* Mouchacca, *Aspergillus ochraceus* Wilhelm and *Trichoderma harzianum* Rifai isolated from non-intercropping plants of phyllosphere, which cleared the high effect of intercropping system on fungal communities. *Fusarium* and *Aspergillus* were the most dominant genera isolated almost from all rhizosphere samples and represented 32.09% and 25.67% of rhizosphere fungal total count, respectively. *Rhizopus stolonifer* came in third place recording 15.2% of rhizosphere fungal total count as shown in Table 9. *Aspergillus, Penicillium* and *Fusarium* genera are the most prevalent fungi on earth, introducing beneficial uses to humans especially in foods and antibiotics production, on the other hand they have harmful roles as food spoilage and plant pathogenic agents (Bennett, 2010). Al-Khateeb (2004) isolated 27 fungal genera, 64 species and 6 varieties from different cultivated plants rhizosphere in Assiut Governorate, the most widespread fungi were *Aspergillus ochraceus, A. sydowii, Botryotricum piluiferum, Emericella quadrilineata, Fusarium solani, Penicillium purpurgenum* and *Stachybotrys chartarum*. *Emericella nidulans* var. *nidulans* (Eidam) Vuillemin, *Fusarium culmorum* (W.G. Smith) Saccardo and *Fusarium lateritium* Nees isolated only from rhizosphere samples, while *Alternaria chlamydospora* Mouchacca, *Aspergillus ochraceus* Wilhelm and *Trichoderma harzianum* Rifai recovered only from phyllosphere samples. Phyllosphere fungi are transient inhabitants of leaf surfaces, hydrophobic and hard substratum is perceived by most fungi as one of the signals for attachment and development on leaf surface (Shaw *et al.* 2006). However, plants with comparable surface hydrophobicity might

differ in their ability to bind spores of different fungi, indicating that other factors are important in host-pathogen recognition (Zelinger *et al.* 2006). The fungal communities are influenced by external and/or internal factors such as nutrient availability, humidity, temperature, leaf age and type, and presence of inhibitors (chemical compounds produced by the plant) (Evueh and Ogbebor, 2008).

Aspergillus was the most dominant genus isolated from all phyllosphere samples and represented 50.87% of phyllosphere fungal total count. *Rhizopus stolonifer* came in second place giving 19.56% of phyllosphere fungal total count (Table 10). Abdel-Sater (2001) recovered twenty fungal species representing thirteen genera from leaf surfaces of onion plant (*Allium cepa* L.), the most prevalent fungi were *Alternaria alternata, Aspergillus niger, A. sydowii, A. versicolor, Cladosporium herbarum, Cochliobolus lunatus, Pleospora herbarum, Setospheria rostrata* and *Ulocladium botrytis*. Fungi species diversity generally analyzed by Species richness (S), the Shannon–Wiener index (H') Simpson diversity index (Ds), and Pielou index (J). These indices tested the homogeneity of the isolated fungal species. These index reflects the microbial community compatibility and healthy which eventually affect the plant health. Higher values of the biodiversity index indicate large variation in fungal communities of different plants specially in intercropping plants. In our results highest values of Shannon–Wiener index (H') more than 1 cleared high species variation between the tested samples especially when Simpson diversity index (D_s) value becomes near 1 value. Jiang *et al.* (2016) reported that higher Shannon's index and closer Simpson's index to 1 gives higher fugal variation which eventually reflect stronger adaption capacity in the environmental condition changes. Li *et al.* (2016) revealed that species richness (S) reflects the richness of fungi associated with plants; the larger values indicated the richer number of fungal species.

Conclusion

Cropping system in order to increase the cropping area in the newly reclaimed soils is a must. Yield and its attributes of faba bean was decreased when intercropped with onion, garlic and fennel compared with sole faba bean in both seasons. Drip irrigation produced the maximum yield and its attributes of faba bean as compared with sprinkler irrigation in both seasons. sole onion and garlic had the highest values of yield under drip irrigation as compared with intercrop with faba bean and sprinkler irrigation in the both season. However, fennel intercrop in faba had the highest value of yield under sprinkler irrigation as compared with sole fennel and drip irrigation in the both seasons.

Land equivalent ratio (LER) values were greater than one, in both seasons. The highest LER value of 1.92 was observed when fennel intercrop with faba bean under sprinkler irrigation in the second season, while the lowest value of 1.05 was observed onion intercrop with faba bean under sprinkler irrigation in the first season. The values of competitive ratio under sprinkler irrigation were greater than The values drip irrigation in both seasons. The highest value of monetary advantage index (MAI) 6519.96 was observed intercropping faba bean with garlic under drip irrigation in the second season. Plant microbial communities affected highly by the intercropping and various irrigation systems which indicated in the biodiversity index. For both bacteria and fungi; the total counts in plants phyllosphere were high in sprinkle irrigation than drip irrigation system while in rhizosphere was high in drip irrigation than sprinkle irrigation system which related to the moisture content around the plant. Sole cropping contained higher microbial number than cropping system, this action may due to the interaction effects between different plants in the same place.

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تحميل الفول البلدي مع بعض المحاصيل وتأثيره على الإنتاج وميكروبات الفيللوسفير والريزوسفير تحت نظم الري الحديثة

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الملخص

تم إجراء تجربتان حقليتان بمحطة بحوث عرب العوامر- محافظة أسيوط خلال الموسمين ٢٠١٦-٢٠١٧ و٢٠١٧-٢٠١٨. قيمت الدراسة الحالية تأثير تحميل الفول البلدي مع بعض المحاصيل على الإنتاج وميكروبات الفيللوسفير والريزوسفير تحت نظم الري الحديثة. تم إجراء تجربتان منفصلتان تعرضت كل تجربة من التجربتين لاحد نظم الري (الري بالرش والري بالتنقيط) كل تجربة تحتوي على سبعة معاملات من النظم المحصولية (الفول البلدي منفرد- بصل منفرد- ثوم منفرد- شمر منفرد؛ وتحميل الفول البلدي مع البصل، الثوم والشمر). أوضحت النتائج أن طول النبات، عدد الافرع/نبات، عدد القرون/نبات محصول البذور/نبات، وزن ١٠٠ بذرة ومحصول البذور/فدان للفول البلدي انخفضت عندما تم التحميل مع البصل أو الثوم أو الشمر مقارنة بالزراعة المنفردة للفول البلدي في كلا الموسمين. الري بالتنقيط أنتج أقصى إنتاجية للمحصول ومساهماته للفول البلدي مقارنة بالري بالرش في كلا الموسمين. الزراعة المنفردة للبصل والثوم أعطت أعلى قيم من المحصول تحت نظام الري بالتنقيط بالمقارنة بالتحميل مع الفول البلدي والري بالرش في كلا الموسمين. ومع ذلك، فإن تحميل الشمر مع الفول البلدي أنتج أعلى قيمة من المحصول تحت نظام الري بالرش مقارنة مع الزراعة المنفردة للشمر ونظام الري بالتنقيط في كلا الموسمين. ولوحظ أن أعلى قيمة لمعدل استغلال الأرض وهي ١,٩٢ عند تحميل الفول البلدي مع الشمر تحت نظام الري بالرش في الموسم الثاني. وكانت قيم معدل التنافس للبصل والثوم والشمر المحملة مع الفول البلدي أكبر من الزراعة المنفردة للفول البلدي في كلا الموسمين. وقد لوحظ أعلى قيمه للعائد الاقتصادي وهي ٦٥١٩,٩٦ عند تحميل الفول البلدي مع الثوم تحت نظام الري بالتنقيط في الموسم الثاني. لوحظ تأثير كبير للنظم المحصوليه ونظم الري المختلفة على تعداد الكائنات الدقيقة في الرايزوسفير والفيللوسفير. وجد ان تعداد الفطريات والبكتيريا المتواجدة في الفيللوسفير أعلي تحت نظام الري بالرش عن التنقيط بينما في الريزوسفير كانت أعلي في حالة الري بنظام التنقيط عن الرش. دلت الدراسة على ان الزراعة المنفردة سجلت تعداد ميكروبي أعلي من النظم المحصوليه. ارتفاع قيم معامل التنوع البيولوجي تدل على تنوع كبير في المجتمعات الفطرية المتواجدة في النباتات المختلفة خاصة في التحميل.