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Effect of Intercropping Practices of Globe Artichoke (*Cynara scolymus* L.) with Garlic (*Allium sativum* L.), N-rates and Biofertilizers on Growth, Productivity, Land Equivalent Ratio and Microbiological Properties in Globe Artichoke Rhizosphere

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INTERCROPPING is planting of two or more species that are simultaneous in a period of their growth cycle. Hence, the present study aimed to investigate the growth, yield, land equivalent ratio (LER) and various chemical and microbiological properties in rhizosphere of globe artichoke and green garlic grown in the field solely (PS) and intercropped (IS1 and IS2). The study was conducted in Baramoon Res. Sta., Mansoura, Egypt during the two seasons of 2012/13 and 2013/14. It also studied the effect of microbial inoculants and N-fertilizer rates.

Results showed that there were growth and yield adaptability between globe artichoke and green garlic in intercropping. Treatment of IS1 (globe artichoke x garlic equal 4000 x 42000 plant fed^{-1}) with microbial inoculants (*Azotobacter* + *Azospirillum*) and 75 kg N fed^{-1} produced the highest yield as land equivalent ratios (LERs), it was the highest LERs (1.50) yield compare to sole culture, increased. The microbial populations were in the highest values with the same treatment IS1. Monocropping of globe artichoke or green garlic had detrimental effects on soil microbial communities. These findings indicate that intercropping globe artichoke with garlic could be an ideal farming system to effectively improve yield, quality, microbial activity and economics to develop sustainable globe artichoke production.

Keywords: Globe artichoke, Green garlic, Intercropping, Land equivalent ratios (LERs), Yield, Economics and Biofertilization.

Intercropping gives several advantages such as the exploitation of the place and time economically, increases the total production of the unit area, covers with consumer needs of the farmer, flows of income throughout the year and utilizes resources efficiently, in addition to many other advantages. Globe artichoke (*Cynara scolymus* L.) is mostly grown on a mono-cropping pattern in Egypt, which carries many problems with it, such as deterioration of soil physicochemical properties (Ye *et al*., 2004), adverse effects on soil structure (Huang *et al*., 2006) and the build-up of soil-borne diseases and autotoxicity (Ahmad *et al*., 2013). So mono-cropping system has negative impacts on the soil physical properties and structure, thus intercropping system is the better option to address these problems. Also, globe artichoke takes a long time in the field, about eight months, and sows in rows at 0.8 to 1.0 m apart and 1 to 1.2 m apart (large distance) and plant growth will be limited during the long growth periods (in the range of 3: 4 months), which requires farmers to look for suitable crop to grow with globe artichoke without reducing its final yield. Choosing different intercropping models of garlic with globe artichoke and soil inoculants are considered the target to provide farmers with scientific knowledge for achieving more land utilization and net return.

Intercropping is the practice of growing two or more crops in close proximity in the same growing season, aims to maximizing yield through synergistic interactions between different cultivated plants and promote efficient use of resources (Awal *et al*., 2006). Intercropping is now becoming more important to improve soil quality and increase crop productivity (Li *et al*., 1999). This cropping system is particularly significant in developing countries, where arable land is suppose to be limited.

Garlic (*Allium sativum* L.) is known for its antimicrobial components mainly allicin. The exudates secreted by the rooting system of garlic can cause pronounce effects on soil structure and ecology. Furthermore, it resulted in some significant impact on the growth patterns, yield and quality of intercropped plant (Ahmad *et al*., 2013, Wang *et al*., 2014). Hence intercropping of garlic with globe artichoke can be productive in overcoming problems created during continuous cropping system.

Garlic has effectively been incorporated into an intercropping system as a companion crop due to its allelopathic and antimicrobial effects. Some studies have reported that garlic intercropping can prevent insect attack (Mogahed, 2003, Lai *et al*., 2011) and weed invasion (Mueller *et al*., 1998). Recent research demonstrated that intercropping with garlic, green garlic (Xiao *et al*., 2012) and onion (Zhou *et al*., 2011) can alleviate problems associated with continuous cropping (soil sickness) of cucumbers under protected cultivation. However, most attention has been directed to the yield and growth parameters, as well as soil biological characteristics.

Studies showed that soil microbial diversity, soil enzyme activities and crop yield could be affected by land management practices (Carney *et al*., 2004, Acosta-Martinez *et al*., 2010). Intercropping is becoming more important in improving the utilization of land resources and increasing crop productivity (Li *et al*., 2001). Some studies have demonstrated that intercropping can relieve soil sickness by improving soil quality (Ahmad *et al*., 2013) and the ecological microclimate (Olasantan, 1996). In addition, intercropping can effectively improve nutrient mobilization in the rhizosphere and nutrient acquisition based on inter-specific root interactions (Inal *et al*. 2007). Most studies on nutrient uptake and transfer have focused on legume-cereal intercropping systems (Adu-Gyamfi *et al*., 2007). Nitrogen (N) input and transfer occurs in this intercropping system based on the specific biological nitrogen fixation of leguminous crops (Adu-Gyamfi *et al*., 2007). Some of rhizosphere microorganisms fix the atmospheric nitrogen (by symbiotic relationship with the plant or beneficial free living bacteria, *Azotobacter* and *Azospirillum*, which living in the soil), dissolve the phosphorus and potassium of the soil (Sturz and Christie, 2003), control plant stress, and protection plant diseases (Lugtenberg and Kamilova, 2009), stimulate the growth of plants by helping to control pathogenic organism (Vessey, 2003) and also, could provide defense against pathogen attack (Siddiqui, 2004). Plant growth promoting rhizobacteria (PGPR) are able to produce plant growth promoting substances and antibiotics (Haas and Défago, 2005). The uptake and mobilization of micronutrients is also influenced by intercropping, especially Fe in peanut and maize intercropping systems (Zheng *et al*., 2003). Except for legume-cereal intercropping systems, other studies reported that the turmeric, maize and onion intercropping systems improved nutrient uptake compared to that of either of the sole crops (Sivaraman and Palaniappan. 1996). In this respect, Zhou *et al*. (2011) demonstrated that intercropping cucumber with onion or garlic increased cucumber productivity and improved soil enzyme activities, soil bacterial and fungal community structures at different levels. Also, Song *et al*. (2007) indicated that intercropping (wheat/faba bean, wheat/maize, and maize/faba bean) had significant effects on microbiological and chemical properties in the rhizosphere, which may contribute to the yield enhancement by intercropping.

The long-term use of mineral fertilizers, particularly high rates of nitrogen fertilizers, may be harmful, as it leads to increase gaseous nitrogen losses, deteriorating physical, chemical and biological properties of the soil and, eventually, reduce safety of the plant products obtained (Barabasz *et al*., 2002). Accordingly, attention has been focused on the use of different organic substrates and biofertilizers (microbial inoculants) as an alternative and/or a supplement to costly mineral fertilizers (Sofi and Wani, 2007).

The objective of this research is to investigate the possibility of planting garlic with globe artichoke under different intercropping patterns and different N-rates with soil amendments on growth, early and total yield, land equivalent ratio, microbial population and economic evaluation in globe artichoke.

Materials and Methods

Plant materials and growth conditions

The experiment was conducted during the two seasons of 2012/13 and 2013/14 in a clay loam soil at Baramoon experimental farm (latitude $30^{o}11^{/}$ N, longitude 28^{o} $26^{/}$ E and altitude +7 m above sea level), Mansoura Hort. Res. Sta., Egypt. The soil contained 0.04% available N, 1.3% organic matter and pH 7.9 (average two seasons). Extractable soil P and K levels in the plots used in this 2-year trial were in the range of 11.0 to 11.5 mg kg^{-1} for P and 295 to 310 mg kg^{-1} for K. Local climate is hot and dry during the summer and warm in winter. Temperature range between a minimum average of 8.5°C at night and a maximum average of 40.2°C at day in summer (during the seasons of study). Globe artichoke cv. Green globe and garlic cv. Balady were used in this experiment.

Experimental arrangement, treatments and crop management

A split-plot design based on randomized complete blocks was used. Two intercropping systems plus sole crop were assigned to the main plots and the soil amendment treatments were devoted to the sub-plots. Treatments were replicated three times to make a total of 36 plots for one crop (3x4x3).

Each experimental sub-plot consisted of 4 rows and each row was 4m long and 1m width. The old grown pieces (stumps) of globe artichoke were treated pre-planting with fungicides for 30 minutes. The planting dates were 15 and 19 of August in the 1^{st} and 2^{nd} seasons, respectively. Garlic was intercropped and planted during the 4^{th} and 5^{th} of September for both seasons. Nearly uniform cloves were soaked in running water for 12 h before planting. The preceding crop was maize in the two seasons.

Two intercropping models in which globe artichoke were intercropped with standing normal green garlic, in addition to two monoculture crops were used as follows:

- *Intercropping system one (IS1):* intercropping garlic with globe artichoke by planting globe artichoke in rides 1 m wide in hills spaced 1 m apart on one side of the ride, giving 4200 plant fed^{-1} (100% of the sole crop) and planting garlic on the other side in hills 10 cm apart to give 42,000 plant fed^{-1} (30% of the sole crop).
- *Intercropping system two (IS2):* intercropping garlic with globe artichoke by planting globe artichoke in rides 1 m wide in hills spaced 1 m apart on one side of the ride, giving 4200 plant fed^{-1} (100% of the sole crop) and planting garlic on the other side in hills 15 cm apart to give 28,000 plant fed^{-1} (20% of the sole crop).
- *Pure stand of globe artichoke (PS_{ga}):* stumps were hand-planted in rides 1 m, width spaced 1 m apart between pieces (1.0 plant m^{-2}), giving 42000 plant fed^{-1}.
- *Pure stand of green garlic (PS_{gg}):* cloves were hand-planted on both sides of the ridges (60 cm) at 10 cm apart (16.67 plant m^{-2}), giving 140,000 plant fed^{-1}.

Four soil amendments were compared as nitrogen N at a rate of 100 kg fed^{-1} (control), microbial inoculants (*Azotobacter* and *Azospirillum*), microbial inoculants + 75 kg N fed^{-1} and microbial inoculants + 50 kg N fed^{-1}. Nitrogen fertilizer (ammonium sulphate 20.5% N) was added at two equal doses, *i.e.*, the first with 1^{st} irrigation, and the second with 3^{rd} irrigation. The rate of biofertilizers inoculation was 5 ml of each culture for each plant, as sub-soil, in the rhizosphere area with 2^{nd} irrigation (Selim and El-Saei, 2001). All treatments received the same total amount of phosphorus (75 kg fed^{-1}) and potassium (96 kg fed^{-1}) fertilizer for the season, which were applied with nitrogen application. All the recommended cultural practices for growing both crops were performed when it was necessary.

The source of microorganisms and the inocula preparation

Two active bacterial isolates were used in this study. *Azotobacter chroococcum* and *Azospirillum lipoferum* were isolated from rhizosphere of onion plants and identified in Agricultural Microbiology Department, Fac. Agric., Damietta Univ., Damietta, Egypt. *A. chroococcum* and *A. lipoferum* were maintained on a modified Ashby's medium (Abdel-Malek and Ishac, 1968) and modified nitrogen-deficient semi-solid makate medium (Dobereiner, 1978), respectively at 5°C.

Inocula were prepared by subculturing of *A. chroococcum* and *A. lipoferum* mother culture on 100 ml of sterilized modified Ashby's medium and modified nitrogen-deficient semi-solid makate medium, respectively in 250 ml conical flasks and incubated at 30°C for 10 days on a rotary shaker at 160 rpm. The cultures were counted and the count was corrected by adding sterilized water to give the final count (1x108 cell/ml). The rate of biofertilizers inoculation was 5 ml of each culture for each plant, as sub-soil, in the rhizosphere area (Selim and El-Saei, 2001).

Data and measurements

Globe artichoke: After 120 days from planting date, five samples of plant shoots from each sub-plot were taken and oven-dried at 60°C for 72 h and foliage dry weight per plant was determined. All flower heads of plants in each plot were harvested during the periods from November-February and March-May, to study yield distribution and to determine early and total yields. At harvest time, samples of receptacle in dry weight were analyzed for inulin and nitrogen content according to Winton and Winton (1958) and Bremner (1965) using a semi-micro Kjeldahl apparatus, respectively.

Green garlic: A random sample of ten plants was taken from each plot after 120 days from planting to estimate plant dry weight, bulb weight and bulb diameter. At 150 days from planting, plants in the two central rows of each plot were weighed in kg and converted to record as total yield (ton/fed). Samples of the dried cloves were ground, wet digested and determined N content (Bremner, 1965).

Land equivalent ratios: $LER = L_A + L_B = Y_A/S_A + Y_B/S_B$

L_A and L_B are the LERs for the individual crops (globe artichoke and green garlic). Y_A and Y_B are the individual crop yields in intercropping, where S_A and S_B are their yields as sole crops.

Economic evaluation: Total yield of globe artichoke and green garlic of intercrops as compared with sole crop were recorded at harvest and cost benefit ratio worked out.

Nitrogenase activity and microbial population count of soil samples

The nitogenase activity of two bacterial isolates (*A. chroococcum* and *A. lipoferum*) was determined using the acetylene reduction assay (Hardy *et al*., 1973) in National Center for Agric. Res. in El-Dokki, Giza, Egypt. Values of nitrogenase activity were recorded as n moles C_2H_4/ml/h.

Poured plate method was used to determine the total bacterial count and the total yeast and fungi count. Total bacterial count of soil samples were determined according to (APHA, 2009) using nutrient agar medium (Difco, 2009). After inoculation all plates were incubated at 30°C for 3 days before counting. Total yeast and fungi count of soil samples were determined using potato dextrose agar (PDA) medium (Oxoid, 2006). The plates were incubated at 25°C for 6 days. After the incubation period, developed colonies were counted per each plate. The mean count of colonies on plates was recorded to represent fungal count (APHA, 2009). Most probable numbers (MPN) technique was used to determine the count of *A. chroococcum* and *A. lipoferum*. Three decimal dilutions for each sample in three replicate tubes were employed. The number of positive tubes was recorded. The count of bacteria per gram of soil sample was calculated from standard table according to Sutton (2010). *A. chroococcum* and *A. lipoferum* counts of soil samples were determined on modified Ashby's medium (Abd El-Malek and Ishac, 1968) and modified nitrogen-deficient semi-solid makate medium (Dobereiner, 1978), respectively, and incubated at 30°C for 10 days.

Statistical analysis

Data were analyzed by ANOVA and the difference of the treatments was compared using the least significant difference (LSD) test at $P \leq 0.05$ according to Snedecor and Cochran (1989).

Results and Discussion

The effect of intercropping with green garlic and soil amendments on the biomass, yield and chemical composition of globe artichoke

The interaction effect between intercropping patterns and soil inoculants, had significant differences on shoot dry weight per plant, early yield, total yield, inulin and N contents (receptacle) of globe artichoke, in both seasons (Table 1 and Fig. 2 & 3). Globe artichoke pure stand (PS_{ga}) or intercropped to green garlic IS1 with 100 kg or 75 kg N plus *Azotobacter* and *Azospirillum* inoculants exhibited significant positive effects on shoot biomass compared with other treatments. Significant positive effects of globe artichoke PS_{ga} or garlic intercropping IS1 and 100 kg or 75 kg N plus *Azotobacter* and *Azospirillum* inoculants were recorded on total yield, inulin and N content, in the two seasons of growth (Table 1). Also, IS2 with 100 kg or 75 kg N plus microbial inoculants had a significant effect on total yield per feddan. A significant effect of globe artichoke solely (in both seasons) or intercropped with green garlic (1^{st} season only) on early yield of globe artichoke was observed in Table 1.

TABLE 1. Effect of intercropping globe artichoke with green garlic and soil amendments on shoot dry weight, yield, yield components and chemical analysis of globe artichoke in 2012/13 and 2013/14 seasons.

No.	Treatments		Shoot D.W./plant (g)		Earl yield (ton/fed.)		Total yield (ton/fed.)		Inulin (mg/g D.W.)		N % (in receptacle)	
	Intercropping	Soil amendments	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
1	Globe artichoke pure stand (PS1)	N (100 kg fed^{-1})	216.73	206.97	1.379	1.196	9.197	8.238	1.66	1.57	2.90	2.94
2		*Azotobacter* + *Azospirillum*	149.77	133.40	0.904	0.657	4.680	4.023	1.04	0.93	2.02	1.72
3		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	218.63	211.17	1.410	1.204	9.300	8.335	1.67	1.60	2.94	2.96
4		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	183.27	169.30	1.071	0.934	7.950	6.991	1.31	1.13	2.46	2.41
Means (PS)			192.10	180.20	1.191	0.998	7.782	6.897	1.42	1.31	2.58	2.51
5	Globe artichoke x Garlic (IS1)	N (100 kg fed^{-1})	206.70	198.90	1.234	1.096	8.793	7.955	1.60	1.54	2.89	2.83
6		*Azotobacter* + *Azospirillum*	143.46	129.50	0.804	0.534	4.414	3.930	0.90	0.92	1.74	1.63
7		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	206.30	200.13	1.291	1.134	8.904	8.023	1.62	1.55	2.90	2.85
8		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	164.33	162.90	0.889	0.681	7.473	6.739	1.15	1.07	2.43	2.25
Means (IS1)			180.20	172.86	1.057	0.861	7.396	6.662	1.34	1.27	2.49	2.39
9	Globe artichoke x Garlic (IS2)	N (100 kg fed^{-1})	196.53	183.90	1.084	0.889	8.338	7.282	1.53	1.50	2.76	2.70
10		*Azotobacter* + *Azospirillum*	131.03	119.07	0.673	0.503	3.974	3.341	0.93	0.83	1.66	1.48
11		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	200.50	187.40	0.694	0.870	8.306	7.220	1.50	1.41	2.67	2.64
12		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	167.53	155.63	0.802	0.713	7.067	6.205	1.18	1.06	2.20	2.06
Means (IS2)			173.90	161.50	0.813	0.746	6.921	6.012	1.29	1.20	2.32	2.22
Soil amendments		N (100 kg fed^{-1})	206.66	196.59	1.232	1.064	8.776	7.825	1.60	1.54	2.852	2.82
		Azotobacter + *Azospirillum*	141.42	127.32	0.794	0.565	4.356	3.765	0.99	0.89	1.804	1.61
		Azotobacter + *Azospirillum* + 75 kg N fed^{-1}	208.48	199.57	1.131	1.069	8.837	7.859	1.59	1.52	2.836	2.82
		Azotobacter + *Azospirillum* + 50 kg N fed^{-1}	171.71	162.61	0.924	0.776	7.498	6.645	1.21	1.09	2.363	2.24
LSD 5% intercropping x soil amendments			14.90	10.30	0.306	0.051	1.143	1.268	0.15	0.19	0.20	0.24
LSD 5% intercropping			4.17	5.12	0.201	0.033	0.677	0.235	0.08	0.05	0.16	0.057
LSD 5% soil amendments			8.60	5.95	0.176	0.029	0.660	0.732	0.09	0.11	0.11	0.14

Treatments:
1. IS1 x N (100 kg fed^{-1}) 2. IS1 x *Azotobacter* + *Azospirillum* 3. IS1x *Azoto.* + *Azosp.* + 75 kg N 4. IS1x *Azoto.* + *Azosp.*+ 50 kg N
5. IS2 x N (100 kg fed^{-1}) 6. IS2 x *Azoto.* + *Azosp*. 7. IS2x *Azoto.* + *Azosp.*+ 75 kg N 8. IS2x *Azoto.* + *Azosp.*+ 50 kg N

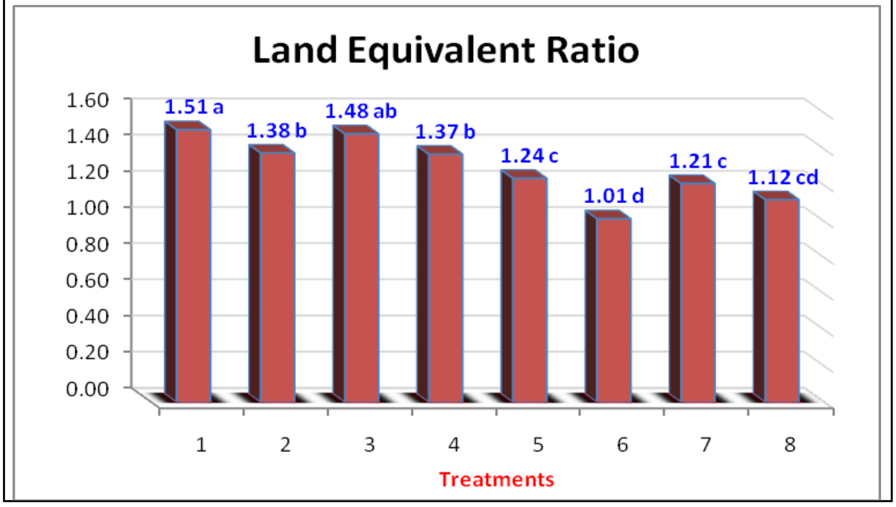

Fig. 1. Effect of intercropping globe artichoke with green garlic and soil amendments on land equivalent ratio LER in average of 2012/13 and 2013/14 seasons.

Fig. 2 and 3. Globe artichoke-green garlic intercropping (Baramoon Experi. Farm, H. R. I.).

When intercropping systems were kept constant, soil amendments had a significant effect on biomass, yield and chemical composition. Application of N at 100 kg or 75 kg N plus *Azotobacter* and *Azospirillum* inoculants exhibited significant positive effects on these parameters compared with other both treatments (Table 1).

No significant differences were detected in total yield and inulin content between pure stand PS_{ga} and IS1 on globe artichoke treatments in both seasons (Table 1).

These pronounced positive effects on the shoot biomass, total yield, inulin content and N concentration on globe artichoke plants may be attributed to the fact that plants under intercropping system markedly changed the population of soil microbial communities (Table 3). Intercropping with green garlic increased the concentration of bacteria and fungi in the rhizosphere as compared to mono-cropping. This may be due to the interaction of soil microorganisms and root exudates (garlic), which may affect soil microbial communities (Table 3). Previous studies showed that the amount and kind of root exudates differ between plant species, and these differences can stimulate species specific shifts in the soil microbial community (Uren, 2000). Root exudates contain root-specific metabolites that might have critical ecological impacts on soil macro and micro biota as well as on the whole plant. Through the exudation of a wide variety of compounds, roots affect the soil microbial community in their immediate vicinity, supporting beneficial symbioses, alter the chemical and physical properties of the soil, and inhibit the growth of competing plant species (Bertin *et al*., 2003). Our results (Table 1 and 3) are also in agreement with Keswani *et al*. (2003), who stated that intercropping increased the bacterial rhizosphere soil ratio of maize and soybean, whereas fungi rhizosphere soil ratio showed a decrease in both cases when compared to sole crop condition. Functional diversity and metabolic activity of soil microbial community improved under intercropping. Intercropping could significantly increase the quantity of soil bacteria in both maize and peanut root areas (Lixuan *et al*., 2007, Zhang *et al*., 2009). As demonstrated by Wu *et al*. (2010) that intercropping aromatic plants in sandy soil in pear orchard had good regulatory effects on the soil microbial quantity. In another study conducted by Chai *et al*. (2005) that intercropping significantly enhanced the number of total microbial population in the rhizosphere as compared to monoculture cropping. Also, Ahmad *et al*. (2013) concluded that intercropping pepper with green garlic improved soil microbial and biochemical properties as compared to monocropping.

The effect of intercropping with green garlic and soil amendments on the dry weight, yield, bulb characteristics and N-chemical composition of garlic

The interaction effect between globe artichoke intercropped with green garlic and soil amendments had significant effects on the dry weight of plant, bulb characteristics, yield and N-nutrient element in the green garlic plants (Table 2).

Intercropping IS1 with soil amendments (N at 100 kg or 75 kg N plus *Azotobacter* and *Azospirillum* inoculants) of globe artichoke-green garlic and garlic pure stand PS_{gg} had significant effect on bulb weight, bulb diameter and N concentration of green garlic plants. Only green garlic PS_{gg} exhibited a significant effect on plant dry weight compared with other treatments, in both seasons. The dynamic change in total yield of green garlic due to intercropping presented in Table 2 and it showed that garlic PS_{gg} and N (100 kg) or N (75 kg) plus *Azotobacter* and *Azospirillum* inoculants had a significant effect on total yield, in both seasons.

When intercropping systems were kept constant and soil amendments varied, it was observed that N amendments at 100 kg or 75 kg plus soil inoculants with *Azotobacter* and *Azospirillum* had significant effect on all studied growth and yield as well as bulb quality parameters, in both seasons (Table 2).

Only pure stand of green garlic PS increased significantly the dry weight, yield, bulb characteristics and N-content of garlic in both seasons of study.

Garlic intercropped with their abundant nutrients increase the input of nutrient compared to the monocrop (N content, Table 2). The increases in growth and yield of green garlic could be related to soil organic matter (green garlic produced numerous roots, which may be remained as a carbon source in the soil after harvesting) and available nutrients (Wang *et al*., 2014). In our experiment, it was found that enhancement of growth and yield of green garlic under intercropping system may be due to better availability of plant nutrients and root exudates from garlic plants (Ahmad *et al*., 2013, Wang *et al*., 2014). These results are supported by Zhou *et al*., (2007) that garlic root exudates significantly increased the chlorophyll content of the tested vegetables due to better absorption of nutrients in intercropped treatments. Also, Olga *et al*., (2007) showed that when tomato plants intercropped with marigold resulted in higher ($p \leq 0.05$) net photosynthetic rate and chlorophyll content as compared to the control. Dong *et al*., (2008) reported that concentration of 20 $mg.ml^{-1}$ of garlic bulb aqueous extracts promoted peroxidase (POD) and catalase (CAT) activities, while higher concentrations inhibited POD and CAT activities. It is known that, Catalase is an enzyme of the anti-oxidant system and it prevents accumulation of H_2O_2 in the cells. It has been demonstrated that CAT activity can be induced in plant species (Jumin and Jin, 2010). Peroxidase plays role in auxin catabolism, production and breakdown of hydrogen peroxide. The anti-oxidant capabilities of POD make it as an important factor in the integrated defense response of plants to a variety of stresses (Cipollini, 1998). The inoculation with *Azotobacter* and *Azospirillum* plus nitrogen fertilizers under intercropping systems enhanced root elongation, surface area and changes root morphology, root dry weight, phytohormones and auxins production as compared with non-inoculated under monocultures, which improve the growth of entire root system, which results in enhanced mineral and water uptake (Ahmad *et al*., 2013).

The effect of intercropping globe artichoke with green garlic and soil amendments on land equivalent ratio LERs

The productivity of globe artichoke-garlic mixture and land equivalent ratios (LERs) were assessed in terms of yield production throughout the two growing seasons (Figure 1). Results showed that the LERs values of yields both globe artichoke-garlic mixture substantially exceeded that of their corresponding monoculture. Treatments of IS1 with 100 kg or 75 kg N plus microbial inoculants (Tables 1 and 3) had significant effect on LERs compared with other treatments. Calculating the land equivalent ratio (LERs) 1.51 and 1.48 were observed, respectively.

TABLE 2. Effect of intercropping globe artichoke with garlic and soil amendments on plant dry weight, bulb characteristics, total yield and nitrogen concentration of green garlic in 2012/13 and 2013/14 seasons.

No.	Treatments		Plant D.W. (g)		Bulb weight (g)		Bulb diameter (cm)		Total yield (ton/fed.)		N % (in clove)	
	Intercropping	Soil amendments	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
1	Garlic pure stand (PS2)	N (100 kg fed^{-1})	15.63	14.44	59.07	51.97	5.30	4.93	12.750	12.462	2.38	2.28
2		*Azotobacter* + *Azospirillum*	8.78	9.24	36.23	33.17	3.17	3.03	5.697	5.350	1.35	1.34
3		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	15.68	14.60	61.00	53.50	5.47	5.37	13.637	12.632	2.34	2.21
4		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	12.03	10.62	48.50	40.57	4.47	3.87	11.828	10.940	1.77	1.67
		Means (PS)	13.03	12.25	51.20	44.80	4.60	4.30	10.978	10.346	1.96	1.88
5	Globe artichoke x Garlic (IS1)	N (100 kg fed^{-1})	14.82	13.97	56.27	46.33	5.03	4.70	7.617	6.107	2.20	2.25
6		*Azotobacter* + *Azospirillum*	8.69	9.18	35.37	29.63	3.10	2.67	2.292	2.313	1.09	1.23
7		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	14.97	14.10	58.37	51.80	5.23	4.80	7.352	6.353	2.19	1.83
8		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	11.24	10.23	45.47	36.83	3.77	3.43	4.731	4.655	1.67	1.46
		Means (IS1)	12.43	11.87	48.87	41.15	4.28	3.90	5.498	4.857	1.79	1.69
9	Globe artichoke x Garlic (IS2)	N (100 kg fed^{-1})	14.31	13.40	53.93	48.10	4.87	4.60	4.626	3.984	2.13	1.86
10		*Azotobacter* + *Azospirillum*	7.71	6.96	34.00	28.53	3.27	2.67	1.009	0.913	1.06	1.04
11		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	13.94	13.26	51.23	46.30	4.70	4.40	4.604	3.987	2.10	1.78
12		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	10.36	10.02	41.63	35.10	3.70	3.07	2.515	2.639	1.59	1.43
		Means (IS2)	11.58	10.91	45.20	39.51	4.13	3.68	3.189	2.876	1.72	1.53
Soil amendments		N (100 kg fed^{-1})	14.92	13.98	56.42	48.80	5.07	4.74	8.331	7.518	2.24	2.13
		Azotobacter + *Azospirillum*	8.40	8.46	35.20	30.44	3.18	2.79	2.998	2.859	1.17	1.21
		Azotobacter + *Azospirillum* + 75 kg N fed^{-1}	14.86	13.99	56.87	50.53	5.13	4.86	8.531	7.650	2.21	1.94
		Azotobacter + *Azospirillum* + 50 kg N fed^{-1}	11.21	10.29	45.20	37.50	3.98	3.46	6.358	6.078	1.68	1.52
LSD 5% intercropping x soil amendments			0.33	0.30	3.11	4.62	0.85	0.63	0.945	0.291	0.20	0.25
LSD 5% intercropping			0.13	0.11	1.18	3.86	0.23	0.41	0.295	0.180	0.08	0.23
LSD 5% soil amendments			0.19	0.17	1.80	2.66	0.49	0.37	0.546	0.157	0.11	0.15

TABLE 3. Effect of intercropping globe artichoke with green garlic, nitrogen levels and biofertilization with *Azotobacter* and *Azospirillum* on the soil microbial population count (log_{10} cfu*/g soil) (average of two seasons).

No.	Treatments		Total bacterial count	Total yeast and fungi count	*Azotobacter chroococum* count	*Azospirillum lipoferum* count
	Intercropping	Soil amendments				
1	Globe artichoke pure stand (PS1)	N (100 kg fed^{-1})	8.72	3.86	6.66	4.27
2		*Azotobacter* + *Azospirillum*	8.85	3.49	7.77	5.30
3		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	9.09	3.57	7.86	5.57
4		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	8.94	3.46	7.80	5.43
5	Garlic pure stand (PS2)	N (100 kg fed^{-1})	8.74	3.88	6.61	4.07
6		*Azotobacter* + *Azospirillum*	8.83	3.54	7.72	5.23
7		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	9.08	3.65	7.83	5.51
8		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	8.91	3.54	7.79	5.27
9	Globe artichoke x Garlic (IS1)	N (100 kg fed^{-1})	8.69	3.32	6.71	4.50
10		*Azotobacter* + *Azospirillum*	8.84	3.47	7.94	5.54
11		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	10.20	3.91	8.24	5.91
12		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	8.96	3.42	7.85	5.57
13	Globe artichoke x Garlic (IS2)	N (100 kg fed^{-1})	8.68	3.21	6.69	4.36
14		*Azotobacter* + *Azospirillum*	8.83	3.43	7.90	5.50
15		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	9.84	3.84	7.96	5.64
16		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	8.93	3.77	7.84	5.49

*cfu: colony forming unit

Since the idea of land equivalent ratio in most cases, is the most important comparison between yield of the main crop in mixture and its yield in pure stand, it is rather expected that the combination of component species in mixture will be more productive than the species grown as a sole crops.

The result obtained were strongly coincided with the definition of land equivalent ratio in that the combination of component species in the mixture were more productive than the same species when grown as sole crops. However, the LER ratio, in almost all cases, was greater (over one) than the sole which interpreted as advantage of mixture over sole (Figure 1). Similarly, Mazaheri and Overysi (2004) documented that an LER of 1.0 or less indicating that no difference in yield between the intercrop and the collections of monoculture, while any value greater than 1.0 indicates that yield advantage for intercropping. Moreover, Dariush *et al*. (2006) confirmed that LER is taken as a measure of relative yield advantage for example LER of 1.2 indicates that the area planted to monocultures would need to be 20% greater than the area planted to intercrop to produce the same combined yields (i.e. 20% more land would be required as a sole crop to produce the same yield as intercropping). In addition, Ressende in 2000 could reach lettuce and radish intercropping more beneficial to obtain pure cultures and LER of intercropping 2.30 has been reported (Ressende *et al*. 2000). Mix garlic and beans culture, its usefulness in pure culture showed 2.80 LER (Lameei hervan, 2003).

The effect of intercropping globe artichoke with green garlic and soil amendments on microbial population

Nitrogenase is the enzyme used by some microorganisms to fix atmospheric nitrogen (N_2). The nitogenase activity was determined using the acetylene reduction assay, the values of nitrogenase activity were 6995.8 and 59.634 n moles C_2H_4/ml/h for *Azotobacter chroococcum* and *Azospirillum lipoferum*, respectively. Our results was similar to Mahmoud *et al.* (2011) who reported that, the nitrogen fixing bacteria (*Azotobacter* and *Azospirillum*) which isolated from onion rhizosphere resulted a highly active of nitrogenase and so the microorganisms should be used as active biofertilizer.

Table 3 show the effect of soil addition in the globe artichoke pure stand (PS_{ga}) on the soil microbial population. The highest value of total bacterial count (9.09 $\log_{10}$ cfu/g soil) was achieved with *Azotobacter* + *Azospirillum* + 75 kg fed^{-1}, but the lowest value (8.72 $\log_{10}$ cfu/g soil) was done when 100 kg nitrogen / fed. Total yeast and fungi count average from 3.46 to 3.86 $\log_{10}$ cfu/g soil. The present of fungi in the soil produce organic acids which increase the availability of nutrients and mineral for plants to absorb and uptake. The highest values of *A. chroococum* count and *A. lipoferum* count was in the treatment No. 3 being 7.86 and 5.57 $\log_{10}$ cfu/g soil, respectively, on the other hand, the lowest values was in the treatment No. 1 being 6.66 to 4.27 $\log_{10}$ cfu/g soil, respectively. Our results were agreement with Ghazal *et al*. (2011) who study the response of wheat plants to EM (Effective Microorganisms) and they found that, the high count of fungi (36.33 x 10^2 cfu/g soil) in the soil did not have any effect on the nitrogen fixer bacteria.

The observations of Abd El-Fattah (2001) may be explained why this value was high in the present of *Azotobacter* and *Azospirillum*. They reported that, the inoculation with *Azotobacter* and *Azospirillum* enhanced root elongation, surface area and changes root morphology, root dry weight, phytohormones and auxins production as compared with non-inoculated, which improve the growth of entire root system, which results in enhanced mineral and water uptake. They also added that, the presence of *Azospirillum* help plants to overcome the stress.

Table 3 also shows that, the effect of soil additions in the garlic pure stand (PS_{gg}) on the soil microbial population. The values of total bacterial count, total yeast and fungi count, *A. chroococum* count and *A. lipoferum* count take the same trend with the above experiment. The highest values were achieved with *Azotobacter* + *Azospirillum* + 75 kg fed^{-1}, but the lowest values were obtained when 100 kg N fed^{-1}.

The effect of soil amendments in the globe artichoke x garlic (IS1) on the soil microbial population were also, presented in Table 3. The maximum values of total bacterial, total yeast and fungi count, *A. chroococum* count and *A. lipoferum* count were archived when *Azotobacter* + *Azospirillum* + 75 kg fed^{-1} was used being 10.20, 3.91, 8.24 and 5.91 log_{10} cfu/g soil. But the lowest values were 8.69, 3.32, 6.71 and 4.50 log_{10} cfu/g soil in the case of 100 kg N fed^{-1}.

This observation may be explain by the following, plant growth-promoting rhizobacteria (PGPR) and fungi can facilitate plant growth indirectly by reducing plant pathogens, or directly by facilitating the uptake of nutrients from the environment, by influencing phytohormone production (*e.g.* auxin, cytokinin, or giberallin), and/or by enzymatic lowering of plant ethylene levels. In addition to facilitating the growth of plant, plant growth-promoting microorganisms can protect plants from the deleterious effects of some environmental stresses including flooding, drought, salt and phytopathogens. Plant growth-promoting bacteria were tested on growth of tomato, pepper, canola, bean and lettuce under salt stress, and these biological treatments ameliorated the deleterious effect of salinity (Yildirim *et al*., 2006).

Many authors explain this observation as following, *Azospirillum* release broad-spectrum of plant growth regulator, *i.e.* auxins, gibberellins and cytokinins (El-Khawas, 1995). *A. brasilense* produced high quantities of indole-3-acetic acid (IAA) and tryptophol. IAA might have a positive effect on host growth due to production of plant growth substances (El-Khawas *et al*., 2000). Interactions between *Azospirillum* sp. and many plant species under saline stress have yielded contradictory evidence, some interactions were beneficial and some were somewhat negative (Bacilio *et al*., 2004).

The effect of a biofertilizer (a mixture of growth promoting of non-symbiotic N-fixing bacteria of genera *Azotobacter*, *Azospirillium* and *Klebsiella*) on growth, yield, quality and storability of two garlic (*Allium sativum* L.) cultivars was studied by Abdel-Razzak and El-Sharkawy (2013) and they found that, the treatment with biofertilizer result increasing and improvement in the garlic bulbs yield and quality as well as bulbs storability.

The effect of soil amendments in the globe artichoke x garlic (IS2) on the soil microbial population were also take the same pattern of the above experiment (Table 4), where the values of total bacterial count, total yeast and fungi count, *A. chroococum* count and *A. lipoferum* count were in the highest values with *Azotobacter* + *Azospirillum* + 75 kg fed^{-1} was added, but the lowest values were resulted when 100 kg nitrogen/fed was applied. Our results were in the same line with those Selim and El-Saei (2001) who studied the effect of composed inoculation with N_2-fixing bacteria and vesicular-arbuscular mycorrhiza on growth and nutrition of Mung bean and that found that, the highest numbers of total bacterial count was 22.77 x 10^6 cfu/g soil and *Azospirilla* was 65.61 x 10^4 cfu/g soil in the soil inoculated with triple inocula in the presence of 1/2 dose of nitrogen fertilizer.

The effect of intercropping globe artichoke with green garlic and soil amendments on economic evaluation

The economic evaluation of the results reveal that the globe artichoke-green garlic mixed culture IS1 and N at a rate of 75 kg fed^{-1} with microbial inoculants (*Azotobacter* and *Azospirillum*) show the highest net return (£.€ 11,136 fed^{-1}, 1 £.€ = 0.13 $ and 1 feddan = 0.42 hectare)**,** in comparison with other treatments. Thus, this treatment proved to be economical for intercropping production. As a support for the present results, Amanullah *et al*. (2006) indicated that one possibility for lowering the cost of planting would be the use of intercropping practices.

Conclusion

It is of great importance to take advantage of intercropping in the efforts for maintaining biodiversity and sustainable agricultural development. During this study globe artichoke and garlic based intercropping system improved physiological properties of globe artichoke. Also, we can concluded that intercropping of globe artichoke with green garlic and the application of N at 75 kg fed^{-1} as well as microbial inoculants with *Azotobacter* and *Azospirillum* had good impact on growth, yield, land equivalent ratios and various chemical and microbiological prosperities of globe artichoke. Globe artichoke intercropped with green garlic recorded the highest net profit for small farmers.

TABLE 4. Economic evaluation of the tested treatments (average the two seasons of study).

No.	Treatments		Total yield* (Ton fed^{-1})		Total costs** (£.€ fed^{-1})	Additional cost*** (£.€ fed^{-1})	Gross return (£.€ fed^{-1})	Net return (£.€ fed^{-1})	Order
	Intercropping	Soil amendments	Globe artichoke	Garlic					
1	Globe artichoke pure stand (PS1)	N (100 kg fed^{-1})	8.718		6780	900	13948	7168	7
2		*Azotobacter* + *Azospirillum*	4.352		5980	100	6962	0982	14
3		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	8.818		6655	775	14108	7453	6
4		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	7.471		6430	550	11953	5523	9
5	Garlic pure stand (PS2)	N (100 kg fed^{-1})		12.940	7800	900	9705	1905	11
6		*Azotobacter* + *Azospirillum*		5.524	7000	100	4145	-2855	16
7		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}		13.135	7675	775	9851	2176	10
8		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}		11.384	7225	325	8538	1313	13
9	Globe artichoke x Garlic (IS1)	N (100 kg fed^{-1})	8.374	6.862	7620	840	18545	10925	2
10		*Azotobacter* + *Azospirillum*	4.172	2.303	6870	890	8402	1532	12
11		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	8.464	6.853	7545	890	18681	11136	1
12		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	7.106	4.693	7320	890	14889	7569	5
13	Globe artichoke x Garlic (IS2)	N (100 kg fed^{-1})	7.81	4.305	7270	490	15725	8455	4
14		*Azotobacter* + *Azospirillum*	3.658	0.961	6520	540	6573	53	15
15		*Azotobacter* + *Azospirillum* + 75 kg N fed^{-1}	7.763	4.296	7195	540	15642	8447	3
16		*Azotobacter* + *Azospirillum* + 50 kg N fed^{-1}	6.636	2.577	6970	540	12550	558	8

*Total yield as average of the two seasons. (1 ha = 2.4 fed.)

**Total costs include leasehold, labor, PK fertilizers, pesticides, microelements and other cultural practices which equal nearly £.€ 5880 and 6900 for globe artichoke and garlic, respectively, plus additional cost. (1 $ = 7.5 £.€) ***Additional cost was calculated according to the following prices: Price of N fertilizer £.€ 900 (100 kg fed^{-1}), *Azotobacter* + *Azospirillum* £.€ 100 and finally, price of produce £.€ 1600/ton of Globe artichoke and £.€ 700 of green garlic.

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تــأثير معــاملات تحميــل الخرشــوف والثــوم ومعــدلات النيتــروجين والتسـميد الحيـوي علــي النمـو والمحصـول ونسـبة معادلــة الأرض والمحتوي الميكروبي في ريزوسفير نبات الخرشوف

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تعطي معاملات التحميل عدة مزايا مثل استغلال المكان والوقت بشكل اقتصادي ، وزيادة الإنتاج الكلي من وحدة المساحة مع تغطية الاحتياجات الاستهلاكية للمزارع وانسياب دخله علي مدار السنة، بالإضافة إلي مزايا أخري عديدة..

لذلك.. أجريت تجربتان حقليتان في المزرعة البحثية بالبرامون- محطة بحوث البساتين بالمنصورة، خلال موسمي ٢٠١٢/٢٠١٣ و٢٠١٣/٢٠١٤ بغرض دراسة تأثير معاملات تحميل نباتات الخرشوف والثوم الأخضر، بالإضافة إلي معاملات إضافات أرضية تتمثل في التسميد النيتروجيني بمعدلات مختلفة والتسميد الحيوي بلقاحات الأزوتوباكتر و الأزوسبيريللم.

استخدم تصميم القطع المنشقة مرة واحدة في ٣ مكررات.. حيث وزعت معاملات التحميل المختلفة علي القطع الرئيسية وتشمل: ١- زراعة الخرشوف منفردا علي مصاطب عرض ١م، مسافة الزراعة ١م (٤٢٠٠ نبات/فدان)، ٢- زراعة الثوم منفردا علي خطوط عرض ٦٠سم علي ريشتين، مسافة الزراعة ١٠سم (١٤٠٠٠٠ نبات/فدان)، ٣- تحميل الثوم علي الخرشوف (المحصول الرئيسي) (نظام التحميل الأول) والزراعة علي مصاطب عرض ١م وزراعة الثوم علي جانب واحد من المصطبة ومسافة الزراعة ١٠سم (٤٢٠٠ نبات خرشوف x ٤٢٠٠٠ نبات ثوم) وتمثل نباتات الثوم في هذا النظام ٣٠٪ من الزراعة المنفردة، و٤- تحميل الثوم علي الخرشوف (نظام التحميل الثاني) والزراعة علي مصاطب عرض ١م وزراعة الثوم علي جانب واحد من المصطبة ومسافة الزراعة ١٥سم (٤٢٠٠ نبات خرشوف x ٢٨٠٠٠ نبات ثوم) وتمثل نباتات الثوم في هذا الثوم ٢٠٪ من الزراعة المنفردة. كما تشمل المعاملات الشقية: ١- التسميد النيتروجيني بالمعدل الموصي به (١٠٠ كجم/فدان)، ٢- التلقيح الميكروبي ببكتريا الأزوتوباكتر و الأزوسبيريللم، ٣- التسميد النيتروجيني بمعدل ٧٥ كجم ن/فدان + اللقاح الميكروبي، و٤- التسميد النيتروجيني بمعدل ٧٥ كجم ن/فدان + اللقاح الميكروبي.

أوضحت النتائج حدوث فروق معنوية في جميع الصفات محل الدراسة مثل: قياسات النمو، المحصول الكلي، المحتوي الميكروبي، بالإضافة إلي نسبة معادلة الأرض، حيث تفوقت معنويا معاملات تحميل الخرشوف مع الثوم (نظام التحميل الأول) مع إضافات النيتروجين بمعدل ٧٥ كجم/فدان بالإضافة إلي التلقيح الميكروبي للنباتات القائمة في معظم الصفات محل الدراسة والمحتوي الميكروبي من البكتريا والفطريات النافعة في ريزوسفير نباتات الخرشوف، وبلغت نسبة معادلة الأرض ١٥٠٪ مقارنة بالزراعة المنفردة، مع تحقيق هذه المعاملة أعلي صافي ربح للمزارع من نباتي الخرشوف والثوم الأخضر تحت ظروف هذه الدراسة.