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EFFECT OF INTERCROPPING AND FOLIAR FERTILIZERS ON GROWTH, PRODUCTIVITY AND QUALITY OF JERUSALEM ARTICHOKE PLANTS UNDER SANDY SOIL CONDITIONS

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ABSTRACT: The present study investigated the impact of *Helianthus tuberosus* + *Helianthus annuus* and *Helianthus tuberosus* + *Zea mays* L. *everta* intercropping patterrns in comparison of *Helianthus tuberosus* (Jerusalem artichoke) sole crops on Jerusalem artichoke growth, yield components and tuber chemical constituents under different NPK fertilization rates. The NPK fertilization treatments were four N-P-K rates (0-0-0, 20-20-20, 12-28-0 and 5-5-40 ratio) as foliar spray three times/season. This experiment was conducted as a 5×4 split - plot arrangement in a randomized complete blocks design with three replications. It was conducted at the Experimental Farm of Horticulture at El-Kassasein station Research. Ismailia Governorate, Egypt, during two consecutive summer seasons of 2017 and 2018. Results revealed that intercropping Jerusalem artichoke with sunflower or popcorn crops mostly gave the lowest values of growth parameters; yield per plant and per feddan as well as chemical constituents of Jerusalem artichoke compared to sole crop in the two seasons. Also, 20-20-20 of NPK rate recorded significant increase in these parameters compared to the other rates under study and control. In most cases, sole Jerusalem artichoke recorded the highest values in tuber yield per plant and per feddan compared to intercropping systems under all NPK fertilization rates. From competitive indices determination, i.e., land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE%) revealed that, applied Jerusalem artichoke + popcorn intercropping pattern was more efficient than sole cropping system and the other one under study when combined with NPK fertilization at 5-5-40 and 20-20-20 without significant differences between both rates. Aggressivity (A) estimation indicated that Jerusalem artichoke was dominant while sunflower or popcorn components were dominated. The interaction treatment between Jerusalem artichoke+ sunflower intercropping pattern and foliar application with N P K at 20- 20 -20 gave the highest values for net economic return as compared to other treatments in both seasons under Ismailia Governorate conditions.

Key words: Jerusalem artichoke, sunflower, popcorn, intercropping pattern, NPK, yield, LER, ATER, LUE and A.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus*, L.), that is an Angiosperm plant species of Asteraceae family, is also called the sunchoke, topinambur, earth apple and sunroot (**Monti *et al.*, 2005** and **Tassoni *et al.*, 2010**) and a C-3 warm-season species as sunflower, it is a native to temperate regions of North America (**Slimestad *et al.*, 2010**). Stems and tubers of Jerusalem artichoke contain high levels of fructans. Fructans and the fructose resulting from fructans hydrolysis can be applied in human diet or in medical and industrial proposes (**Schittenhelm, 1999**; **Monti *et al.*, 2005**). Jerusalem artichoke is counted one of the main sources for inulin in higher plants (**Saengthongpinit and Sajjaanantakul, 2005**). Moreover, Jerusalem artichoke just now entices the attention of researchers to develop its productivity by application different levels of fertilizers (**Anwar *et al.*, 2011 a**) and intercropping practices (**Epie *et al.*, 2018**).

Popcorn (*Zea mays* L. *everta*) is very extremely popular among naturalist people, because they can easily process it as food (**Chakma *et al.*, 2011**). Also, sunflower (*Helianthus annus* L.) is one of the three remarkable edible oilseed crops cultivated in the

world after soybean and groundnut (**Kumar *et al.*, 2019**).

In Egypt, growing demand for food as a result of a rising population more and more aside from the continual lowering in agricultural land requests a shift to additional productive cropping patterns. Intercropping is a sustainable practice utilized in many developed and developing nations and a fundamental element of agricultural sustainability (**Maffei and Mucciarelli, 2003**). Intercropping has a paramount part in increasing the productivity and constancy of yield in order to enhance environmental and factors resource utilization (**Alizadeh *et al.*, 2010**).

In addition, the macronutrients especially nitrogen (N), phosphorus (P) and potassium (K) are oftentimes distributing as 'primary' nutrients, because shortages of them are extra common than the 'secondary' macronutrients, calcium (Ca), magnesium (Mg) and sulpher (S). Most of the macronutrients are represent 0.1 to 5%, or 100 to 5000 parts per million (ppm), of plant dry tissue (**Wiedenhoeft, 2006**).

Thus, the objective of the present study was to examine the effect of NPK fertilization rate as foliar spray for Jerusalem artichoke under intercropping pattern with sunflower or popcorn crops on the plant growth, yield components, chemical constituents and some competitive indices between intercropping components under Ismailia governorate conditions.

MATERIALS AND METHODS

The present study was conducted at the Experimental Farm of Horticulture at El-Kassasein Distract, Ismailia Governorate, Egypt, during the two consecutive summer seasons of 2017 and 2018. Intercropping patterns (Jerusalem artichoke + sunflower and Jerusalem artichoke + popcorn at 1:1 side ratios in comparison with sole crops of each specie), different NPK fertilization rate (0-0-0, 20-20-20, 12-28-0 and 5-5-40 at 2g / l as foliar spray) and their interaction treatments were used to evaluate plant growth, yield components and chemical constituents of Jerusalem artichoke as well as some competitive indices of Jerusalem artichoke and intercrops components (sunflower and popcorn). These 20 treatments were arranged in a split-plot in randomized complete blocks design with 3 replicates. Intercropping patterns were randomly arranged in the main plots and NPK foliar spray fertilization rate were distributed randomly in the sub plots. The physical and chemical properties of the experimental soil site are shown in Table 1, according to (**Chapman and Pratt, 1978**).

Table 1. The physical and chemical properties of soil during 2017 and 2018 seasons

Physical properties				Soil texture
	Sand (%)	Silt (%)	Clay (%)	
2017	92.80	2.10	5.10	**Sandy**
2018	93.42	1.78	4.80	

Chemical properties									
Characters	**pH**	**Organic matter (%)**	**Calcium carbonate (%)**	**Available nutrients (ppm)**					
				N	**P**	**K**	**Fe**	**Zn**	**Mn**
2017	8.12	0.05	0.23	8.1	6.8	56	4.87	3.42	2.06
2018	8.09	0.07	0.26	7.8	5.7	58	5.14	3.37	2.14

Whole tubers of Jerusalem artichoke (Ja) within the weight range of 20 to 25 g each were planted on 1st May in both seasons. It was transplanted at space of 40 cm between hills, on the one side of the ridge, but seeds of sunflower or popcorn were sown at space of 40 cm in one the other side of the ridge just after irrigation. After three weeks from planting, germinated plants were thinned to one plants/ hill for each component. Experimental plot was 14.4 m^2 (3 × 6.00 m) included 3 ridges; each ridge was 80 cm

width and 6 m in length. The foliar fertilization rates were applied as foliar application at 50, 60 and 70 days after sowing. Each experimental unit received 5 liters of nutrition solution using spreading agent (Super film at a rate of 1ml/l). The untreated control plants were sprayed with tap water.

All plants (Jerusalem artichoke, sunflower and popcorn) received normal agricultural practices whenever they needed. All plants were fertilized with 250 kg/fed. calcium super phosphate (15.5% P_2O_5), 300 kg/fed. ammonium sulphate (20.5 %N) and 150 kg/fed. potassium sulphate (48% K_2O). All fertilizers were divided into three equal portions and were added to the soil after 30, 50 and 70 days from planting and sowing.

Data Recorded

Plant growth

After 120 days from planting of Jerusalem artichoke, plant growth parameters were determined: plant height (cm), number of main branches/plant, number of shoots/plant and total fresh and dry weight/ plant (g). In addition, plant height (cm), and total dry weight/ plant (g) of sunflower and popcorn plants were recorded at the end of experiment during the two seasons.

Yield and its components

At maturity, Jerusalem artichoke plants (180 days after sowing) number of tubers/plant, average tuber weight (g), tuber yield /plant (kg) and tuber yield /feddan (ton). Marketable tuber yield/feddan were determined using good shapes healthy tubers more than or equal 40 gram. Also, seed or grain yield per plant and per feddan of sunflower and popcorn plants, respectively, were measured.

Chemical constituents

Nitrogen, phosphorus and potassium as well as total carbohydrates were determined in Jerusalem artichoke tubers according to the methods described by **Chapman and Pratt (1978)**, Also, inulin content was recorded in Ja tubers according to the method of **Winton and Winton (1958)**.

Competitive indices

a. Land equivalent ratio (LER)

This parameter was determined for Jerusalem artichoke and sunflower or popcorn yield recorded per feddan according to **Mead and Willey (1980)** equation as follows:

LER = La + Lb,

$$L_{\text{Jerusalem artichoke}}\ (La) = \frac{Yab}{Yaa}$$

$$L_{\text{sunflower or popcorn}}\ (Lb) = \frac{Yba}{Ybb}$$

Where La and Lb are the relative yield of Jerusalem artichoke and sunflower or popcorn, respectively, as well as Yaa and Ybb are the yields per feddan of Jerusalem artichoke and sunflower or popcorn, respectively, as sole crops and Yba and Yab are the yields of Jerusalem artichoke and intercrops (sunflower or popcorn), respectively, as intercrop yields of each components.

b. Area time equivalent ratio (ATER)

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

$$ATER = \frac{Yab\ /\ Yaa \times t\,a + Yba\ /\ Ybb \times t\,b}{T}$$

Where: Yab = intercropped yield of Jerusalem artichoke, Yaa = sole yield of Jerusalem artichoke, Yba = intercropped yield of sunflower or popcorn, Ybb = sole yield of sunflower or popcorn, ta = the duration of Jerusalem artichoke in days (180 days), tb = the duration of sunflower (100 days) or popcorn (120 days) in days, and T= the total duration of intercropping system in days (180 days).

c. Land utilization efficiency (LUE%)

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

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

d. Aggressivity (A)

Mc Gilchrist (1965) equation was used to calculated aggressivity value as follows:

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

$$A_{ab} = L_a - L_b \quad \text{and} \quad A_{ba} = L_b - L_a$$

e. Economic feasibility

Economic analysis was calculated according to **Heady and Dillon (1961)** as following:

Gross income (L.E. /fed.) = total yield (tubers/ fed.) × price of ton tubers + yield of shoots produced from topping × price of ton shoots (L.E.)

Net return (L.E. /fed.) = gross income – total cost of production.

Profit margin = net return/ gross income

Return of Pound= net return/ total cost of production

Benefit/cost ratio =gross income / total cost

Statistical Analysis

The statistical layout of this experiment was split-plot experiment in completely randomized block design. Where, intercropping patterns were randomly distributed in the main plots, while NPK fertilization rates were randomly arranged in sub-plots. Each treatment was included three replicates. Data were analyzed according to **Gomez and Gomez (1984)**. The means were compared using computer program of Statistix version 9 (**Analytical software, 2008**).

RESULTS AND DISCUSSION

1. Impact of intercropping patterns, NPK fertilization rates and their interaction treatments on plant growth parameters of Jerusalem artichoke as well as sunflower and popcorn plants:

Data in Table 2 show that, plant height, number of shoots per plant, shoot fresh and dry weight per plant of Jerusalem artichoke (Ja) were significantly decreased with intercropping pattern treatments compared to sole crop in the first and second seasons. While, number of main branches per (Ja) plant insignificantly affected by any intercropping pattern compared to sole crop. Moreover, the shortest plants were obtained from (Jerusalem artichoke + sunflower) intercropping pattern compared to sole crop and the other one under study. Also, the lowest values of fresh or dry weight of shoot / plant were achieved when Jerusalem artichoke intercropped with sunflower in both seasons. The reducing in plant growth parameters may be attributed to the high competition between the two component crops (Jerusalem artichoke + sunflower or popcorn) on sunlight and available nutrients which might be happened with decreasing the plant distance resulting in low growth of Jerusalem artichoke. Plant height and total dry weight of sunflower or popcorn components were significantly decreased with intercropping pattern treatments compared to sunflower or popcorn sole crops in the first and second seasons (Tables 3 and 4). These results are in harmony with those reported by **Lesoing and Francis (1999)** on corn when intercropped with sorghum and/or soybean, **El-Shamy *et al*. (2008)** on guar when intercropped with sunflower and **Gabatshele *et al*. (2012)** on maize when intercropped with cowpeas.

The results tabulated in Tables 2, 3 and 4 indicate that, all foliar NPK fertilization rates significantly increased plant height, number of shoots/plant and as well as shoot fresh and dry weight of shoot of Jerusalem artichoke compared with control. The maximum increases in this connection were recorded with the treatment of N-P-K fertilization at 20-20-20 rate compared with the other ones under study. In the same time, sunflower and popcorn plant height as well as total dry weight per plant of significantly increased with 20-20-20 N-P-K fertilization rate compared to the other rates under study. It is quite recognized that NPK chemical fertilizers could promote plant growth due to the role of N in nucleic acids and protein synthesis, and P as a primary component of the energy complex (ATP and ADP) and phosphoprotein, as well as, the role of K as a activator of numerous enzymes (**Helgi and Rolfe, 2005**). Similar results were stated by **Mansour *et al*. (2001)**, **El-Sharkawy (2003)** and **Anwar *et al*. (2011, b) on J**erusalem artichoke.

Moreover, Jerusalem artichoke growth parameters as well as plant height and total dry weight of sunflower and popcorn were significantly decreased with all combination treatments between intercropping patterns and NPK fertilization rates compared with treatment of (sole crop pattern with NPK fertilization at 20-20-20) in the 2016 and 2017 seasons, in most cases (Tables 2, 3 and 4). The decreasing in plant height, number of main branches and shoots/plant as well as shoot fresh and dry weights/plant due to combination between intercropping pattern and foliar NPK fertilization rates might be attributed to the increasing in inter and intra competition between Jerusalem artichoke and sunflower or popcorn plants for light and nutrients as reported by **Abdelkader and Hassan (2016)**. It is clear that at the highest NPK foliar fertilization rate (20-20-20), there was little competition between plants on nutrients which resulted in the maximum values of plant height, as well as shoot fresh and dry weight per plant of Jerusalem artichoke.

Table 2. Impact of intercropping pattern, NPK fertilization rate, and their interaction treatments on plant growth parameters of Jerusalem artichoke (Ja) plant during 2017 and 2018 seasons

Treatments		Plant height (cm)		Number of main branches/ plant		Number of shoots/ plant		Total fresh weight/ plant (g)		Total dry weight/ plant (g)	
		2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season
Intercropping pattern											
Sole crop (Ja)		218.66	210.67	3.08	3.17	27.25	26.75	1328.80	1240.00	443.61	405.46
Ja + sunflower		167.33	160.58	3.33	3.50	13.50	12.66	1130.00	941.30	373.82	313.56
Ja + popcorn		192.42	184.67	3.08	3.08	25.25	23.99	1142.50	1012.50	382.86	337.24
LSD at 5%		11.45	8.83	N.S.	N.S.	1.96	1.30	58.89	32.72	10.79	22.90
NPK fertilization rate (as % N-P-K ratio)											
0-0-0		164.89	157.00	2.89	2.89	15.67	15.22	893.30	791.70	299.66	259.51
20-20-20		216.55	207.89	3.11	3.22	26.67	25.55	1381.70	1240.00	461.23	414.29
12-28-0		188.22	181.55	3.44	3.56	22.00	21.11	1253.30	1100.00	413.03	356.09
5-5-40		201.55	194.78	3.22	3.33	23.66	22.66	1273.30	1126.70	426.47	378.47
LSD at 5%		10.00	7.71	0.48	N.S.	1.71	1.14	51.46	28.59	9.43	20.01
Interaction effect between intercropping pattern and NPK rate											
Sole crop (Ja)	**0-0-0**	197.33	187.33	3.00	3.00	20.00	21.00	980.00	950.00	329.00	300.07
	20-20-20	235.00	227.00	2.33	2.67	32.00	31.00	1550.00	1420.00	515.55	470.71
	12-28-0	215.00	208.33	3.33	3.33	28.00	27.00	1385.00	1280.00	461.90	411.27
	5-5-40	227.33	220.00	3.67	3.67	29.00	28.00	1400.00	1310.00	468.00	439.79
Ja + sunflower	**0-0-0**	142.33	134.33	3.00	3.00	9.00	7.66	845.00	705.00	283.68	236.68
	20-20-20	192.33	183.33	3.33	3.33	18.00	17.33	1295.00	1100.00	433.75	369.29
	12-28-0	157.33	152.33	3.67	4.00	12.00	11.33	1180.00	970.00	376.00	317.92
	5-5-40	177.33	172.33	3.33	3.67	15.00	14.33	1200.00	990.00	401.85	330.36
Ja + popcorn	**0-0-0**	155.00	149.33	2.67	2.67	18.00	17.00	845.00	720.00	286.30	241.77
	20-20-20	222.33	213.33	3.67	3.67	30.00	28.33	1300.00	1200.00	434.40	402.86
	12-28-0	192.33	184.00	3.33	3.33	26.00	25.00	1195.00	1050.00	401.18	339.07
	5-5-40	200.00	192.00	2.67	2.67	27.00	25.66	1220.00	1080.00	409.57	365.27
LSD at 5%		17.32	13.37	0.81	N.S.	2.97	1.98	89.13	49.51	16.34	34.66

Ja= Jerusalem artichoke

Table 3. Impact of intercropping pattern, NPK fertilization rate, and their interaction treatments on plant growth parameters of sunflower plant during 2017 and 2018 seasons

Treatments		Plant height (cm)		Total dry weight /plant (g)		Seed yield per plant (g)		Seed yield per feddan (kg)	
		2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season
Intercropping pattern									
Sole sunflower (s)		128.00	138.87	45.05	49.62	54.58	53.00	682.25	662.53
Ja + sunflower		107.10	106.07	35.95	33.58	31.43	31.16	392.66	389.41
LSD at 5%		3.55	3.07	2.85	2.04	0.80	0.99	4.10	3.51
NPK fertilization rate (as % N-P-K ratio)									
0-0-0		110.70	116.65	38.05	39.40	39.33	37.98	491.63	474.69
20-20-20		122.50	127.25	42.35	43.93	46.00	45.67	574.94	570.93
12-28-0		117.65	121.85	40.50	40.80	42.02	41.00	525.00	512.44
5-5-40		119.35	124.15	41.10	42.25	44.67	43.67	558.25	545.82
LSD at 5%		4.40	4.07	3.89	4.01	1.71	2.49	5.95	5.64
Interaction effect between intercropping pattern and NPK rate									
Sole crop (s)	**0-0-0**	120.70	132.00	42.60	47.10	51.33	49.33	641.63	616.63
	20-20-20	133.30	144.50	47.20	52.67	57.33	56.33	716.63	704.36
	12-28-0	128.00	138.00	44.90	47.80	54.00	52.33	675.00	654.13
	5-5-40	130.00	141.00	45.50	50.90	55.67	54.00	695.75	675.00
Ja + sunflower	**0-0-0**	100.70	101.30	33.50	31.70	27.33	26.62	341.63	332.75
	20-20-20	111.70	110.00	37.50	35.20	34.67	35.00	433.25	437.50
	12-28-0	107.30	105.70	36.10	33.80	30.03	29.67	375.00	370.75
	5-5-40	108.70	107.30	36.70	33.60	33.67	33.33	420.75	416.63
LSD at 5%		6.23	5.67	5.39	5.23	2.21	3.17	8.13	7.56

Ja= Jerusalem artichoke

Table 4. Impact of intercropping pattern, NPK fertilization rate, and their interaction treatments on plant growth parameters of popcorn plant during 2017 and 2018 seasons

Treatments		Plant height (cm)		Total dry weight /plant (g)		Grain yield per plant (g)		Grain yield per feddan (kg)	
		2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season
Intercropping pattern									
Sole popcorn (p)		186.42	187.40	118.59	113.42	58.50	59.92	731.22	748.91
Ja + popcorn		128.07	130.32	86.95	87.45	37.67	39.67	470.78	494.75
LSD at 5%		4.75	1.79	0.85	1.08	3.53	3.11	6.75	16.35
NPK fertilization rate (as % N-P-K ratio)									
0-0-0		146.00	141.30	94.08	88.35	44.50	46.33	556.19	579.13
20-20-20		170.50	184.65	116.60	117.75	50.83	52.67	635.38	658.32
12-28-0		156.00	155.00	100.15	98.05	47.17	48.50	589.57	604.13
5-5-40		156.50	154.50	100.25	97.60	49.83	51.67	622.88	645.76
LSD at 5%		3.90	4.82	4.06	4.60	1.33	2.29	20.36	16.53
Interaction effect between intercropping pattern and NPK rate									
Sole crop (p)	**0-0-0**	173.30	169.30	107.47	100.70	55.33	57.00	691.63	712.50
	20-20-20	195.70	217.30	134.60	133.60	61.33	62.33	766.63	779.13
	12-28-0	187.00	183.00	115.70	110.90	57.33	58.67	716.63	733.25
	5-5-40	189.70	180.00	116.60	108.50	60.00	61.67	750.00	770.77
Ja + popcorn	**0-0-0**	118.70	113.30	80.70	76.00	33.67	35.67	420.75	445.75
	20-20-20	145.30	152.00	98.60	101.90	40.33	43.00	504.13	537.50
	12-28-0	125.00	127.00	84.60	85.20	37.00	38.33	462.50	475.00
	5-5-40	123.30	129.00	83.90	86.70	39.67	41.67	495.75	520.75
LSD at 5%		8.61	6.11	5.03	5.71	3.71	3.96	25.63	24.93

Ja= Jerusalem artichoke

2. Impact of intercropping patterns, NPK fertilization rates and their interaction treatments on yield components of Jerusalem artichoke as well as sunflower and popcorn plants:

The data illustrated in Table 5 reveal that, average tuber weight, tuber yield per plant and per feddan significantly decreased when Ja intercropped with sunflower or popcorn compared to sole crop in both seasons. Whenever, number of tubers per plant of Jerusalem artichoke significantly increased in the second season only and with no significant influence in the first one compared to sole crop. Also, intercropping pattern treatments between sunflower or popcorn and Jerusalem artichoke decreased each seed yield per plant and per feddan of sunflower and grain yield per plant and per feddan of popcorn compared to sole crop (Tables 3 and 4). These harmonious results can be explained in the light of that the higher population of Ja plants within area unit (feddan) in sole Ja pattern could be condensate the increase of tuber yield per plant in these treatments compared with intercropping patterns under study. Also, **Wang *et al.* (2018)** also have reported similar.

Data listed in Tables 3, 4 and 5 suggest that, tuber number per plant did not significantly affected by NPK fertilization rate in both seasons. In addition, average tuber weight and tuber yield per plant and per feddan significantly increased by using any fertilization rates under study compared to control (unfertilized plants) during the two seasons. The highest values of Jerusalem artichoke, sunflower and popcorn yield components were achieved by 20-20-20 NPK fertilization rate followed by 5-5-40 NPK fertilization on in the first and second seasons. These results are in accordance with those found by **Abd El-Rehim *et al*. (2005)** on Jerusalem artichoke plant.

The data given in Tables 3, 4 and 5 demonstrate that, the interaction treatments between intercropping pattern Jerusalem artichoke + sunflower or popcorn and NPK fertilization at any rate as foliar spray were superior in increasing Jerusalem artichoke, sunflower and popcorn yield compared to the control (intercropping pattern combined with 0-0-0 of N-P-K) under study in both seasons. The enhancing effect of interaction between sole crop pattern and foliar NPK fertilization on tuber yield per plant and per feddan of Ja as well as sunflower and popcorn yield might be due to the role of nutrients on the plant physiological processes and sole crop which was previously mentioned in the case of plant growth as an increase in this parameters might be reflected on yield components of Jerusalem artichoke plant. These results also noticed by **Ghaley *et al*. (2005)** and **Abd-Elghany *et al*. (2017).**

3. Impact of intercropping patterns, NPK fertilization rates and their interaction treatments on chemical constituents of Jerusalem artichoke tubers

Results under discussion in Table 6 indicate that, N, K, carbohydrates and inulin percentages in tuber of Jerusalem artichoke significantly decreased when Ja intercropped with sunflower or popcorn compared to sole crop in both seasons. Generally, the lowest values in this regard were achieved by intercropping pattern of Jerusalem artichoke + popcorn compared to the other one under study, in most cases. Sole crop results in optimum Jerusalem artichoke growth and yield components compared to intercropping patterns, which is one of the factors for higher production by using the different underground resources efficiently and harvesting solar radiation as much as possible and in turn resulting in better chemical constituents especially inulin percentage. Also, **Ansari *et al*. (2015)** on citronella plant based in different intercropping had reported similar results.

As shown in Table 6 that, total nitrogen and inulin percentages significantly increased when Ja plant sprayed by NPK rate at 20-20-20 compared to the other rates under study. In the other words, the highest potassium and total carbohydrates percentages were achieved by spaying with 5-5-40 NPK to the other rates under study. Whenever, phosphorus percentage was obtained from 12-28-0 NPK fertilization rate to the other rates under study. These results hold true in both seasons. Also, **Anwar *et al*. (2011 b)** stated that spraying Jerusalem artichoke plants with nitrogen and potassium of 1% significantly increased chemical constituents of tubers. Similarly, **Filipović *et al*. (2016)** pointed out that NPK fertilization at (5:15:30) ratio led to improve plant carbohydrates % and inulin % of Jerusalem artichoke plant.

The interaction treatments between sole crop pattern and NPK as foliar spray at 20-20-20 (for N and inulin %), 12-28-0 (for P %) and 5-5-40 (for K and total carbohydrates %) were mostly superior in this regard compared to the other ones under study in both seasons (Table 6). The enhancing effect of spraying plants with NPK fertilization on the above-mentioned constituents may be attributed to the reduction in competition between Jerusalem artichoke plants on nutrient resources. These results coincided with those found by **Epie *et al*. (2018)**.

Table 5. Impact of intercropping pattern, NPK fertilization rate, and their interaction treatments on yield components of Jerusalem artichoke (Ja) plant during 2017 and 2018 seasons

Treatments		Number of tubers/ plant		Average tuber weight (g)		Tuber yield/ plant (kg)		Tuber yield/ feddan (ton)	
		2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season
Intercropping pattern									
Sole crop (Ja)		42.75	41.25	47.27	47.70	2.028	1.965	25.344	24.555
Ja + sunflower		42.75	42.50	41.66	38.80	1.780	1.649	22.250	20.588
Ja + popcorn		42.50	42.50	43.76	42.24	1.859	1.795	23.234	22.438
LSD at 5%		N.S.	1.45	1.50	1.89	0.136	0.118	0.319	0.406
NPK fertilization rate (as % N-P-K ratio)									
0-0-0		43.00	42.33	40.06	39.67	1.775	1.678	22.187	20.979
20-20-20		42.33	41.67	46.60	45.75	1.973	1.900	24.667	23.722
12-28-0		43.00	42.33	43.64	42.45	1.877	1.797	23.458	22.448
5-5-40		42.33	42.00	45.61	43.77	1.930	1.837	24.125	22.958
LSD at 5%		N.S.	N.S.	2.33	2.34	0.186	0.997	0.438	0.391
Interaction effect between intercropping pattern and NPK rate									
Sole crop (Ja)	**0-0-0**	43.00	42.00	44.68	42.86	1.950	1.800	24.375	22.500
	20-20-20	43.00	40.00	49.30	52.50	2.120	2.100	26.500	26.250
	12-28-0	43.00	42.00	46.51	46.90	2.000	1.970	25.000	24.595
	5-5-40	42.00	41.00	48.57	48.54	2.040	1.990	25.500	24.875
Ja + sunflower	**0-0-0**	43.00	43.00	38.37	36.86	1.650	1.585	20.625	19.812
	20-20-20	42.00	43.00	44.54	40.00	1.870	1.720	23.375	21.417
	12-28-0	43.00	42.00	40.70	38.57	1.750	1.620	21.875	20.250
	5-5-40	43.00	42.00	43.02	39.76	1.850	1.670	23.125	20.875
Ja + popcorn	**0-0-0**	43.00	42.00	40.12	39.29	1.725	1.650	21.562	20.625
	20-20-20	42.00	42.00	45.95	44.76	1.930	1.880	24.125	23.500
	12-28-0	43.00	43.00	43.72	41.88	1.880	1.800	23.500	22.500
	5-5-40	42.00	43.00	45.24	43.02	1.900	1.850	23.750	23.125
LSD at 5%		N.S.	N.S.	3.80	3.97	0.309	0.189	0.727	0.708

Ja= Jerusalem artichoke

Table 6. Impact of intercropping pattern, NPK fertilization rate, and their interaction treatments on plant growth parameters of Jerusalem artichoke (Ja) plant during 2017 and 2018 seasons

Treatments		Total nitrogen (%)		Total phosphorus (%)		Potassium (%)		Total carbohydrates (%)		Inulin (%)	
		2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season
Intercropping pattern											
Sole crop (Ja)		1.498	1.408	0.411	0.379	2.167	2.057	22.710	22.243	12.498	12.100
Ja + sunflower		1.215	1.203	0.396	0.395	2.118	2.029	22.597	22.127	11.887	11.920
Ja + popcorn		1.148	1.130	0.383	0.391	1.797	1.711	22.467	21.955	11.825	11.933
LSD at 5%		0.089	0.084	0.007	0.006	0.008	0.038	0.118	0.087	0.178	0.045
NPK fertilization rate (as % N-P-K ratio)											
0-0-0		1.253	1.213	0.395	0.364	1.982	1.896	22.420	22.027	11.853	11.910
20-20-20		1.447	1.393	0.390	0.393	1.945	1.892	22.613	22.133	12.233	12.053
12-28-0		1.220	1.190	0.413	0.404	1.957	1.890	22.503	22.083	12.057	11.993
5-5-40		1.227	1.190	0.388	0.392	2.226	2.050	22.830	22.190	12.138	11.980
LSD at 5%		0.217	0.143	0.009	0.009	0.019	0.033	0.112	N.S.	0.221	0.095
Interaction effect between intercropping pattern and NPK rate											
Sole crop (Ja)	**0-0-0**	1.440	1.360	0.410	0.302	2.112	2.011	22.560	22.180	12.150	12.010
	20-20-20	1.700	1.620	0.402	0.400	2.027	2.005	22.750	22.250	12.650	12.200
	12-28-0	1.420	1.320	0.433	0.415	2.095	2.001	22.660	22.200	12.550	12.120
	5-5-40	1.430	1.330	0.400	0.398	2.433	2.211	22.870	22.340	12.643	12.070
Ja + sunflower	**0-0-0**	1.200	1.180	0.395	0.397	2.080	2.000	22.420	22.050	11.750	11.820
	20-20-20	1.330	1.310	0.393	0.390	2.065	1.999	22.620	22.150	12.050	11.990
	12-28-0	1.150	1.170	0.405	0.402	2.060	1.995	22.520	22.100	11.850	11.920
	5-5-40	1.180	1.150	0.392	0.391	2.267	2.120	22.830	22.210	11.900	11.950
Ja + popcorn	**0-0-0**	1.120	1.100	0.381	0.392	1.755	1.677	22.280	21.850	11.660	11.900
	20-20-20	1.310	1.250	0.375	0.388	1.742	1.673	22.470	22.000	12.000	11.970
	12-28-0	1.090	1.080	0.402	0.396	1.715	1.674	22.330	21.950	11.770	11.940
	5-5-40	1.070	1.090	0.373	0.387	1.977	1.820	22.790	22.020	11.870	11.920
LSD at 5%		0.336	0.230	0.015	0.014	0.029	0.062	0.204	0.263	0.374	0.149

Ja= Jerusalem artichoke

4. Impact of intercropping patterns, NPK fertilization rates and their interaction treatments on competitive indices between Jerusalem artichoke and sunflower or popcorn crops

Table 7 reveals that, the land equivalent ratio, area time equivalent ratio and land utilization efficiency values were greater for Jerusalem artichoke and popcorn pattern; there was an advantage of intercropping for take advantage of the resources of the environment. Moreover, intercropping of Jerusalem artichoke and sunflower or popcorn plants at all intercropping patterns under study were more productive than growing them alone (sole crop), as can be seen from the below mentioned values which were greater than 1.00 for LER and ATER and 100% for LUE% in both seasons. This assures the feature of these intercropping patterns to get additional production from the same area of land as compared with the same unit of area in which sole crop is applied. Concerning aggressivity values as listed in Table 7, it is clear that Jerusalem artichoke component crop was the dominant, whereas sunflower or popcorn components were the dominated one. Also, the advantage of growing species (Such aggressivity indices reached to its maximum values (0.303 and 0.254) by utilizing Ja+ sunflower intercropping pattern treatment in 1st and 2nd seasons, respectively. However, multiple cropping (i.e. intercropping pattern or mixed cropping) gives an important role in agriculture in order to the effective utilize of resources, significantly promoting crop productivity compared with that of sole crops (**Li *et al*., 2001**). These results are in agreement with those found by **Dwomon and Quainoo (2012)** on maize + groundnut and **Dua *et al*. (2015)** on potato + maize intercropping pattern.

The calculated data in Table 7 demonstrate that, maximum LER, ATER and LUE% values (1.552 and 1.531, 1.308 and 1.282 as well as 142.98 and 140.64%) were recorded in 5-5-40 NPK fertilization rate in the first and second seasons, respectively. Positive aggressivity values for Jerusalem artichoke showed that Jerusalem artichoke was the dominant specie whereas the negative values for sunflower or popcorn reveal that it was the dominated one. Results show that the highest positive aggressivity of Jerusalem artichoke was recorded with NPK at 12-28-0 as well as without NPK fertilization application during both seasons, respectively. Furthermore, **Abdelkader and Hamad (2015)** on safflower intercropped with fenugreek and fertilized by NPK as foliar spray also have reported similar results.

Data presented in Table 7, indicate that, under interaction effect, land utilization efficiency values were 148.23 and 149.30 % means that, 48.23 and 49.30 feddan, more area would be required by a sole Jerusalem artichoke cropping pattern to equal the yield of intercropping pattern of Ja + popcorn with foliar fertilization at 5-5-40 NPK rate in the first and second seasons, respectively. In this concern, **Mohamed *et al*. (2006)** revealed that intercropping of cassava with cowpea was beneficial in increasing the land use efficiency. In mostly, under intercropping patterns interacted with NPK fertilization rates, Jerusalem artichoke has positive aggressivity values this means that Jerusalem artichoke was the dominant specie whereas the negative values for sunflower or popcorn reveal that it was the dominated one.

Economic returns

The cost benefit analysis was done with a view to observing the comparative cost and benefit trend of jerusalem artichoke cultivation as affected by cultural practices as the fixed costs including land leasehold, seed costs, cultivation, irrigation, fertilizers, harvesting and the variable costs including compost and topping treatments. The details of economic analysis (average two seasons) are presented in Table (8).

The total production cost ranged between LE. 17750 LE. / feddan to 18910 LE. /feddan among the treatments. The highest gross income and net return LE. /feddan were obtained from the combination between (Jerusalem artichoke + sunflower) intercropping pattern and N-P-K foliar fertilization rate at 20-20-20 this treatment gave the best values of gross income and net return (55500 LE./feddan and 36590 LE./feddan), respectively, whereas, the combination between (Jerusalem artichoke + popcorn) intercropping pattern and N-P-K foliar fertilization rate at 0-0-0 recorded the lowest value of gross income and net return L.E/feddan (47752 and 29202 LE./feddan) , respectively (average two seasons), thus this treatments proved to be the economical for jerusalem artichoke production under the condition of this study. With regard to the profit margin, return of pound and Benefit/cost ratio the combination between intercropping pattern (Jerusalem artichoke + sunflower) intercropping pattern and N-P-K foliar fertilization rate at 20-20-20 recorded the maximum values (0.659, 1.935 and 2.935) respectively, meanwhile the combination between (Jerusalem artichoke + popcorn) and N-P-K foliar fertilization rate at 0-0-0 gave the minimum values (0.612, 1.574, 2.574) respectively.

Table 7. Impact of intercropping pattern, NPK fertilization rate, and their interaction treatments on some competitive indices of Jerusalem artichoke (Ja) plant during 2017 and 2018 seasons

Treatments		Land equivalent ratio (LER)		Area time equivalent ratio (ATER)		Land utilization efficiency (LUE %)		Aggressivity values for Ja (Aga)		Aggressivity values for intercrops (Agb)	
		2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season	2017 season	2018 season
Intercropping pattern											
Ja + sunflower		1.452	1.426	1.197	1.166	132.44	129.59	+0.303	+0.254	-0.303	-0.254
Ja + popcorn		1.560	1.574	1.346	1.354	145.28	146.41	+0.274	+0.255	-0.274	-0.255
LSD at 5%		0.027	0.017	0.023	0.019	2.51	1.71	0.009	N.S.	0.009	N.S.
NPK fertilization rate (as % N-P-K ratio)											
0-0-0		1.436	1.482	1.216	1.258	132.63	136.96	+0.295	+0.316	-0.295	-0.316
20-20-20		1.528	1.511	1.283	1.258	140.55	138.47	+0.265	+0.200	-0.265	-0.200
12-28-0		1.509	1.477	1.277	1.243	139.28	135.94	+0.308	+0.262	-0.308	-0.262
5-5-40		1.552	1.531	1.308	1.282	142.98	140.64	+0.287	+0.238	-0.287	-0.238
LSD at 5%		0.36	0.034	0.035	0.033	3.58	3.35	0.040	0.039	0.040	0.039
Interaction effect between intercropping pattern and NPK rate											
Ja + sunflower	**0-0-0**	1.379	1.420	1.142	1.181	126.07	130.06	+0.314	+0.341	-0.314	-0.341
	20-20-20	1.487	1.437	1.218	1.161	135.24	129.91	+0.277	+0.195	-0.277	-0.195
	12-28-0	1.431	1.390	1.184	1.138	130.72	126.42	+0.320	+0.256	-0.320	-0.256
	5-5-40	1.512	1.457	1.243	1.183	137.74	131.97	+0.302	+0.222	-0.302	-0.222
Ja + popcorn	**0-0-0**	1.493	1.543	1.290	1.334	139.19	143.85	+0.277	+0.291	-0.277	-0.291
	20-20-20	1.568	1.585	1.349	1.355	145.86	147.02	+0.253	+0.206	-0.253	-0.206
	12-28-0	1.586	1.653	1.371	1.347	147.84	145.46	+0.295	+0.267	-0.295	-0.267
	5-5-40	1.592	1.606	1.372	1.380	148.23	149.30	+0.271	+0.254	-0.271	-0.254
LSD at 5%		0.050	0.045	0.048	0.044	4.91	4.37	0.050	0.056	0.050	0.056

Ja= Jerusalem artichoke

Table 8. Economic costs for production of Jerusalem artichoke (average one season of 2017) under interaction between intercropping pattern and NPK rate

Treatment		Total cost (L.E./fed.)	Cross income (L.E./fed.)	Net return	Profit margin	Return of pound	B/C Ratio
Sole crop (ja)	**0.0.0**	17750	48750	31000	0.636	1.746	2.746
	20.20.20	18110	51000	32890	0.645	1.816	2.816
	12.28.0	18022	50000	31978	0.640	1.774	2.774
	5.5.40	18030	50100	32070	0.640	1.779	2.779
Sunflower + ja	**0.0.0**	18550	48083	29533	0.614	1.592	2.592
	20.20.20	18910	55500	36590	0.659	1.935	2.935
	12.28.0	18822	51165	32343	0.632	1.718	2.718
	5.5.40	18830	54582	35752	0.655	1.899	2.899
Popcorn + ja	**0.0.0**	18550	47752	29202	0.612	1.574	2.574
	20.20.20	18910	53795	34885	0.648	1.845	2.845
	12.28.0	18822	52088	33266	0.639	1.767	2.767
	5.5.40	18830	52953	34123	0.644	1.812	2.812

Conclusion

Tuber yield components of sole Jerusalem artichoke decreases when intercropped with sunflower or popcorn crops and competitive effect is biggest at the intercropping pattern of Jerusalem artichoke + popcorn. NPK fertilization rates reduces competitive effect of intercropping on *Helianthus tuberosus* yield and application of 5-5-40 ratio followed by 20-20-20 ratio without significant differences between them are very efficient in increasing tuber yield, as compared with unfertilized plants. The efficiency of intercropping patterns, compared to sole crop, is evidenced by the LER, ATER and LUE for seeds of sunflower and popcorn and tuber yields of Jerusalem artichoke plant.

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