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Influence of Different Planting Dates in both summer and Fall Seasons on Growth and Yield on Jerusalem Artichoke Plants

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ABSTRACT

This experiment was carried out during the two successive seasons of 2013/2014 and 2014/2015 at El-Kanater Research Station, El-Kalubia Governorate, to study the effect of planting dates i.e., mid April (control) and planting in the summer season, i.e., mid May, mid June and July 1st and planting in the fall season, i.e., September 1st, mid September and October 1st on plant growth, fresh and dry weight, yield, its components and chemical constituents of Jerusalem artichoke plants (*Helianthus tuberosus* L.) cv. Local. A randomized complete blocks design was used. Results revealed that planting on mid April significantly increased plant height, no. of main and lateral shoots and fresh weight. Moreover, planting on mid April and mid May reflected significant increase in tuber yield, average tuber weight and average tuber volume. Inulin and carbohydrates contents of tubers significantly increased as planting on July 1st and September 1st. While, the highest values of protein content of tuber were recorded in planting on mid April. In general, results concluded that planting Jerusalem artichoke on mid April was the best treatments for enhanced plant growth, yield and its components. Whereas, planting on July 1st and September 1sd in the fall season produced the highest inulin and carbohydrates contents of tubers.

Key words: Jerusalem Artichoke, planting dates, summer, fall, total yield, inulin content, carbohydrates.

Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) is one of the non traditional tuberous crops introduced to Egypt. It has a high nutritional and accumulates high level of fructans in their stems and tubers. Fructan also has other applications for functional food ingredients that are eligible for enhanced function claims and reduced risk of a colorectal cancer and bacteria (Frese, 1993and D" Egidio *et al.,*1998). Fructans and fructose can be used in human diet and diabetics may be due to Jerusalem artichoke tubers actives the pancreas for supplied of body with insulin or in medical and indusial applications (Monti *et al.,* 2005). The tubers are also used to produce alcohol and high inulin (Saengthongpinit and Sajjaanantakul, 2005). A large amount of germplasm has been tested under tropical climates and some accessions are promising for commercial production in tropical regions (Jogloy *et al.,* 2006 and Pimsaen *et al.,* 2010).

The effect of planting dates due to growth conditions, e.g., soil, growth seasons and planting, the effect of growth seasons have been investigated mainly by planting dates. Two groups of Jerusalem artichoke were suited for main and late season production (early Oct.- Feb.\ Mar.). Stopping shoots in July didn't significantly affect the tuber growth of early and main season. Acceptable yields (15-20 t/ha tubers) can be obtained from early Oct. until spring by planting before the end of Apr. (Klug-Andersen, 1992.). In Southeast Asia, Jerusalem artichoke is grown in the rainy and dry seasons. The dry season has lower temperature during October to February (11-16 C), and this low temperature might affect inulin content and tuber yield of Jerusalem artichoke. The main climatic controlling tuber formation is night temperature and day length (Struik and Ewing, 1995). In addition to growth, tuber yield and inulin are important agronomic traits of Jerusalem artichoke, and these characters are affected by photosynthesis (Schbert and Feuerle, 1997). Previous research found that temperature is an important factor affecting growth and yield of Jerusalem artichoke in temperate regions (Kocsis *et*

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*al.,*2007a and b) and also in tropic regions (Pimsaen *et al.,* 2010). Moreover, the spring season growing showed better potato yield by 16 % over than of the fall season (Abubaker, *et al*.,2011.). Puangbut *et al.* (2012) showed that planting Jerusalem artichoke during lower temperature periods (10-16 ^{o}C) reduced the total dry weight. While, inulin content increased when planted during warmer periods (21- 31 degrees c). Also, Amin and Ihsanul (2013) found that the yield of potato was significantly affected by sowing time with the maximum yield (30.21 t/h) was recorded with September 15th compared with September 22th and October 1st sowing. Recently, Zheng *et al.,* (2016) found that spring season (45.94 t/ha) gave the higher on tuber yield of potato than fall season (24.37 t/ha).

Therefore this study was conducted to investigate the effect of different planting dates in both summer and fall seasons on plant growth, yield and chemical components of Jerusalem artichoke.

Material and Methods

The present investigation was conducted at the experimental farm, El-Kanater research station, El-Kalubia Governorate, during the two successive seasons of 2013/2014 and 2014/2015, to study the effects of planting dates on growth, yield and chemical composition of Jerusalem artichoke (*Helianthus tuberosus* L.) cv. Local variety under clay soil conditions.

The average temperatures, relative humidity and sunshine of location are shown in Table (A).

Table A: Location weather data for monthly average maximum and minimum temperatures, average relative humidity and sunshine in 2013 and 2014 during El-Kalubia Governorate.

	2013				2014			
	Temperature (^{o}C)		Relative humidity (%)	sunshine hours	Temperature (^{o}C)		Relative humidity (%)	Sunshine hours
Month	min	max	Average	Average	min	max	Average	Average
January	6.20	24.60	71	6.80	6.70	25.6	72	7.10
April	11.50	38.30	47	9.40	12.70	38.1	49	9.30
May	15.70	43.80	44	10.60	14.40	43.0	46	10.50
June	20.50	46.20	48	12.70	18.51	43.8	48	12.40
July	21.60	38.90	57	11.80	22.30	40.0	56	11.90
August	22.20	40.10	55	11.30	23.10	39.2	56	11.10
September	17.80	42.50	54	10.50	18.20	40.8	53	10.30
October	13.70	37.30	57	9.80	14.10	35.9	57	9.90
November	11.00	33.80	65	7.80	9.90	31.6	65	7.60
December	3.50	29.90	68	6.90	5.80	30.5	67	6.70

These data coated from Central Laboratory for Agricultural Climate (CLAC)

A randomized complete blocks design, with three replicates, was used. The experimental unit consisted of five rows, 1 m wide and 5 m long, having an area of 25 m^2. Average Seed tuber weight was 35-45 g. Seven treatments were used as summer and fall planting dates as follows:- mid April (control) and planting in the summer season, i.e., mid May, mid June and 1 July and planting in the fall season, i.e., 1 September, mid September and 1 October in two seasons. The harvest in summer crop was mid November or 1 December. While, the harvest in fall crop was in late January in both seasons.

The experimental soil was fertilized with organic manure (20 m^3/fed), phosphorus fertilizer (calcium super phosphate P_2O_5) applied at once in 31 units P_2O_5 /fed before planting, Nitrogen fertilizer was added as 40 N units/fed (ammonium sulphate) and potassium fertilizer was added in 72 K_2O units /fed . N and K fertilizers were added two equal doses during growth season, after 30 and 60 days from planting.

Irrigation was regularly carried out at intervals according to weather condition to keep the moisture content of the soil to field capacity.

Data recorded:-

A- Vegetative growth characteristics:-

Three plants from each plot were randomly taken at 60-120 days from planting in summer season and 60 and 90 days from planting in fall season for recording the following measurements:-

1- Plant height (cm).
2- Number of main shoots /plant.
3- Number of lateral shoots /plant.
4- Fresh weight (g /plant) and dry weight (%).

B- Yield and its component:-

1- Total tuber yield per plant and per fed.:-

At the end of each experimental season all tubers were harvested after 150-250 days from planting in summer season and 120 and 150 days from planting in fall season. Collected tubers per plot were determined and total tuber yield per plant as well as per fed. were then calculated.

2- Average tuber weight (g):

Five random tubers were weighed and average tuber weight was calculated**.**

3-Average tuber volume (cm):

Five tubers were randomly taken and tuber volume was determined by using displacement method and average tuber volume was then calculated**.**

C- Chemical components:-

1- Dry matter (%):

One hundred grams of fresh tubers from each experimental plot were weighed, cut into slices then dried in an oven at 50°C until constant weight and the dried slices of tubers were weighed .The dry matter weight / 100g fresh weight of tubers was then calculated**.**

2- Inulin content of tubers:-

Inulin content was determined in tubers according to the method of Winton and Winton (1958).

3- Protein content:-

Protein content of plants and tubers were determined according to A.O.A.C.(2000).

4- Total carbohydrates of tubers:-

It was determined calorimetrically as grams of glucose /100g dry weight of tubers according to James (1995).

5- Determination of nutrient content of plant:-

Mineral contents, i.e., nitrogen, potassium and phosphorus were determined in dry matter of the plants. Total nitrogen was determined according to Kock and Mcmeekin (1924). Phosphorus content

was determined according to Troug and Meyer (1939). Also, potassium percentage was determined by flame photometer according to Brown and Lilliland (1946).

D- Statistical and analysis:-

Data were statistically analyzed and means were compared using Duncan›s multiple range tested as described by Snedecor and Cochran (1989).

Results and Discussion

1- Vegetative growth characters:-

1.1. Plant height:-

The results in Table (1) referred to variations among studied planting dates for plant height during 2013/2014 and 2014/2015 seasons. Whereas the tallest plant height was obtained when planting on mid April while the shortest was on September 1st and mid September. These results might be due to the climatic conditions in El-Kaluobia zone. This differences among studied planting dates were in agreement with the results obtained by Hang and Gilliland (1982) and Hafez(2005). They found that April planting date showed a significant increase in plant height of Jerusalem artichoke.

Table 1: Effect of planting dates on some vegetative growth parameters of Jerusalem artichoke in 2013/2014 and 2014/2015 seasons.

Treatments	Plant height (m)	No.of main Shoots/plant	No.of lateral shoots/plant	Fresh weight /plant (kg.)	Dry weight /plant %
			2013/ 2014		
Mid April (control)	3.14 A	10.10 A	77.39 A	2.75 A	38.17 A
Summer season					
Mid May	2.30 B	6.70 D	27.10 B	1.92 B	36.76 B
Mid June	1.78 D	8.01 BC	20.67 D	1.07 D	35.32 D
July 1st	1.89 C	6.98 CD	22.33 C	1.57 C	23.05 F
Fall season					
September 1st	0.97 F	8.59 B	14.76 E	0.49 E	36.24 C
Mid September	0.93 F	6.53 D	4.36 F	0.40 E	28..96 E
October 1st	1.09 E	8.44 B	4.05 G	0.42 E	21.53 G
2014/ 2015					
Mid April (control)	3.25 A	11.09 A	83.94 A	2.08 A	40.61 A
Summer season					
Mid May	2.35 B	6.06 G	19.07 C	1.12 B	39.48 A
Mid June	1.76 C	6.32 F	16.08 E	0.63 C	38.67 A
July 1st	1.60 D	8.47 C	18.35 D	0.84 BC	32.47 B
Fall season					
September 1st	1.06 E	10.06 B	21.11 B	0.69 C	22.34 D
Mid September	1.13 E	7.78 E	10.26 G	0.58 C	27.57 C
October 1st	1.12 E	8.07 D	11.58 F	0.69 C	13.32 E

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

1.2. Number of main shoots:-

Results in Table (1) clearly indicated that the highest number of main shoots was obtained from mid April planting. On the other hand, the lowest number of main shoots was detected to mid September planting in the tested seasons. Such increment in April planting may be due to the long day

and high temperature which positively affected plant growth characters. On the other side, the decrement in number of shoots in mid September planting could be attributed to the short days and low temperature during plant growth period. These results are in harmony with those obtained by Hafz (2005) who indicated that planting in April produced the highest significant increase in number of main shoots of Jerusalem artichoke compared with planting in February and March.

1.3 Number of lateral shoots :-

Regarding the effect of planting dates on lateral shoots, data in Table (1) indicate that no. of lateral shoots of Jerusalem artichoke plants significantly increased in planting on mid April compared with the other treatments in the two seasons. Results also indicated that the planting on mid September and October 1st significantly decreased the no. of lateral shoots in both seasons. The highest number of lateral shoot on mid April compared with the other planting dates my be due to low light condition in fall season cause a series of shade negative responses such as reduction in no. of lateral shoots as mentioned by Du *et al*., (2013). Obtained results are in agreement with those reported by Abubaker *et al*., (2011) on potato, they found that the highest number of stems / plant was significant in spring season compared with fall season.

1.4. Fresh weight /plant:-

Data in Table 1 appeared that planting on mid April was the best treatment for increasing fresh weight per plant in the two studied years. On the other side, the lowest value was obtained by planting on September and October 1st in the two seasons. These increments in fresh weight could be due to that April plantation has more favour condition for plant growth than other dates and late planting of Jerusalem artichoke delays canopy development and reduce the time available for tuber bulking. These results coincide with those mentioned by Hang and Gilliland (1982) and Hafez (2005) April planting date was the most favorable for increasing the fresh weight of Jerusalem artichoke. Kocsis *et al*., (2007, b) and Pimsaem *et al.*, (2010) found that lower temperature reduced plant growth of Jerusalem artichoke.

1.5 Dry weight /plant:-

The obtained results in Table (1) shows that dry weight % significantly increased in plants planted on mid April in the first season. While, planting on mid April, mid May and mid June gave the highest significant values of dry weight in the second season. The results agree with those reported by Hang and Gilliland (1982) and Hafez (2005) who recorded that dry weight of Jerusalem artichoke reached the maximum value (15.7 t/ha) when planted on mid April. Lower temperature in the season reduced total dry weight of Jerusalem artichoke (Kocsis *et al*., 2007, b and Pimsaem *et al*., 2010).

2- Yield and its components:-

2.1. Total tuber yield \plant (kg) and per fadden (ton):-

The results in Table (2) showed that planting on mid April and mid May gave the highest productivity of tuber yield per plant and per fed. compared with the other tested treatments in the first season. While, planting on April 15th significantly increased tuber yield per plant and per fed. in the second season (30-32 ton \fed.). While, planting on mid June and mid September gave the lowest productivity (9.84-10.32 ton\ fed.). Such results reflected the same findings of Khalid, *et al*.,(1990), Kawakami *et al.,*(2005) and Hassanpanah *et al*., (2009) who reported that the maximum potato yields were obtained in planting at 25 April and May 13th and minimum potato yield were found in planting at 25 July. These plants need more time for plant growth in suitable temperature and moisture, so tuber yield increasing is rational on potato. Hafez(2005) April plantation date significantly increased the total yield of Jerusalem artichoke.

The results support previous finding that shoot dry weight, tuber formation and yield were reduced when Jerusalem artichoke was planted during low temperature and humidity condition in tropical regions (Jogloy *et al.,* 2006, Kocsis *et al.*, 2007, b and Pimsaem *et al*., 2010). Amin and Ihsanul (2013) found that the yield of potato was significantly affected by sowing time and the maximum yield (30.21 t/h) was recorded with September 15th sowing compared with September 22th and October 1st . The summer season (April 15th, May 15th, June 15th and July 1st) gave the highest productivity of tuber yield per fed compared with fall season (September 1st ,September 15th and October 1st).

Table 2: Effect of planting dates on total tubers yield and yield component characters of Jerusalem artichoke in 2013/2014 and 2014/2015 seasons.

Treatments	Total yield/ plant (kg)	Total yield/fed (ton)	Average tuber weight (g)	Average tuber volume (cm^3.)
			2013/2014	
Mid April (control)	3.72 A	30.00 A	105.53 A	129.50 A
Summer season				
Mid May	2.63 AB	25.21 AB	97.04 A	120.40 B
Mid June	1.23 D	11.02 CD	69.01 C	67.64 G
July 1st	1.33 D	10.30 D	65.89 C	90.33 D
Fall season				
September 1st	1.71 C	12.24 C	86.89 B	102.10 C
Mid September	1.09 D	8.54 E	87.13 B	84.30 E
October 1st	1.22 D	10.61 CD	60.67 C	74.52 F
2014/2015				
Mid April (control)	4.04 A	31.43 A	117.20 A	109.50 A
Summer season				
Mid May	2.94 B	23.17 B	91.88 C	107.80 A
Mid June	1.47 E	10.06 F	82.58 D	55.67 D
July 1st	2.15 D	17.46 E	60.73 E	65.86 C
Fall season				
September 1st	2.44 C	20.67 C	108.10 B	108.30 A
Mid September	1.22 F	9.84 F	88.23 CD	78.39 B
October 1st	2.15 D	18.63 D	66.23 E	61.36 C

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

The results supported the previous findings of Abubaker *et al.,* (2011) and Shahram and zayn (2013) on potato, The spring season showed better yield by 16 % over the fall season. Zheng *et al.,* 2016 found that spring season gave the higher tuber yield (45.94 t/ha)of potato than fall season (24.37 t/ha).

It might be attributed to the favorable climatic conditions prevailing during this plantation which was reflected on the stimulation of plant growth and increased yield. The main climatic factor controlling tuber formation is night temperature and day length as obvious in Table (A) and these results are in agreement with those obtained by Struik and Ewing (1995).

2.2- Average tuber weight and volume:-

Presented data in Table (2) indicate the effect of planting dates during two seasons on average tuber weight and volume of Jerusalem artichoke, The results reveal that planting on mid April reflected significant increment in average tuber weight (117.3 g) and volume (129.5 cm.) during both seasons. This result indicated that April planting dates are suitable for cultivation in this area. In other words, this climate enhanced the plants to build good growth which was reflected on tuber weight and size. Similar results were reported by Hafez (2005) who indicated that plants grown on April planting date showed significant increases in average tuber weight and size.

3- Chemical analysis:-

3.1. Dry matter %:-

The results listed in Table 3 clearly show that dry matter percentage significantly increased in planting on mid April (27.22%) in the first season. Whereas, planting on mid April (control) and mid May significantly increased dry matter percentage in the second season. These results agree with those reported by Joshi *et al.,* (1994) who showed that Jerusalem artichoke tubers grown in summer season who gave dry matter(26.8 -25.3%).

3.2. Inulin content of tubers (g/100g):-

It is obvious from the data in Table 3 that inulin content was significantly increased when planting on July 1st, September 1st and mid September compared with the other treatments. These results are in harmony with those obtained by Chubey and Dorrell,1982. Tuber content of inulin in Columbia Jerusalem artichoke cultivar which was harvested in late September reached 18-20% in fresh weight, while those harvested in spring decreased to 16.4%. Hafez(2005) showed that a significant increase in inulin content was noticed in tubers of plants grown in April planting date compared with March and February planting dates. The results my be due to low temperature, increased humidity and low sunshine hours which important for having high inulin during the dry season (Table A). inulin content of Jerusalem artichoke increased when planted during warmer periods (21- 31 degrees c) and inunil content increased in fall season (16.46) compared with summer season (14.55). (Puangbut *et al.* 2012).

Table 3: Effect of planting dates on some chemical components of Jerusalem artichoke tubers in 2013/2014 and 2014/2015 seasons.

Treatments	Dry matter (g/100g)	Inulin (g /100g)	Carbohydrates (%)	Protein (%)
		2013/2014		
Mid April (control)	27.60 A	14.37 C	25.57 D	12.06 A
Summer season				
Mid May	25.35 B	14.18 C	31.27 BC	10.06 BC
Mid June	23.51 C	14.92 BC	28.90 CD	8.68 CD
1-July1st	20.56 D	16.32 A	37.78 A	7.75 D
Fall season				
1 September1st	23.47 C	16.45 A	33.51 AB	10.88 AB
Mid September	22.43 C	15.85 AB	30.42 BC	8.63 CD
1-October1st	19.53 D	15.95 A	30.65 BC	11.44 AB
		2014/2015		
Mid April (control)	29.23 A	14.53 C	30.61 E	15.63 A
Summer season				
Mid May	28.43 AB	15.04 C	35.42 C	11.19 B
Mid June	25.68 CD	15.49 BC	32.99 D	7.81 C
July1st	18.48 E	16.96 A	46.37 A	7.94 C
Fall season				
September1st	26.70 BC	16.14 AB	42.94 AB	10.50 B
Mid September	26.40 C	16.25 AB	36.27 C	6.94 C
October1st	23.81 D	15.34 BC	38.61 B	12.00 B

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

3.3. Total carbohydrates percent of tubers:-

Concerning carbohydrate percentage of tubers, data in Table 3 show that carbohydrate percentage of tuber was significant increased in planting on July 1st and September 1st in both seasons. These results are in agreement with Madsen, (1997) who showed low carbohydrate content of southern Eurasian Watermilfoil planted in summer season which may be related to higher water temperatures, which may be causing a mid-summer reduction in growth due to temperature stress and

high dark respiration rates during long growth period. April plantation date significantly increased the carbohydrate percentage of tuber compared with March and February planting dates (Hafez, 2005).

3.4. Total protein percent of tubers:-

Results presented in Table 3 clearly showed that planting on mid April produced the highest values of protein percentage compared with the other tested planting dates during the two seasons. The values of protein content of tubers ranged from 15.63 – 7.96% in both seasons.

1.6. Nitrogen, phosphorus, potassium and protein contents of plant:-

Obtained data in Fig. (1-4) reported that there were significant differences in nitrogen and protein contents of plants. Planting on mid April was the best treatment for increasing nitrogen and protein content of plants in the first season. While, nitrogen and protein content of plants were significantly affected when the plants planted on mid April, mid June, September 1st and October 1st in the second season. In this concern, Hafez (2005) found that the highest content of nitrogen content was detected to plants of April plantation compared with those of March and February.

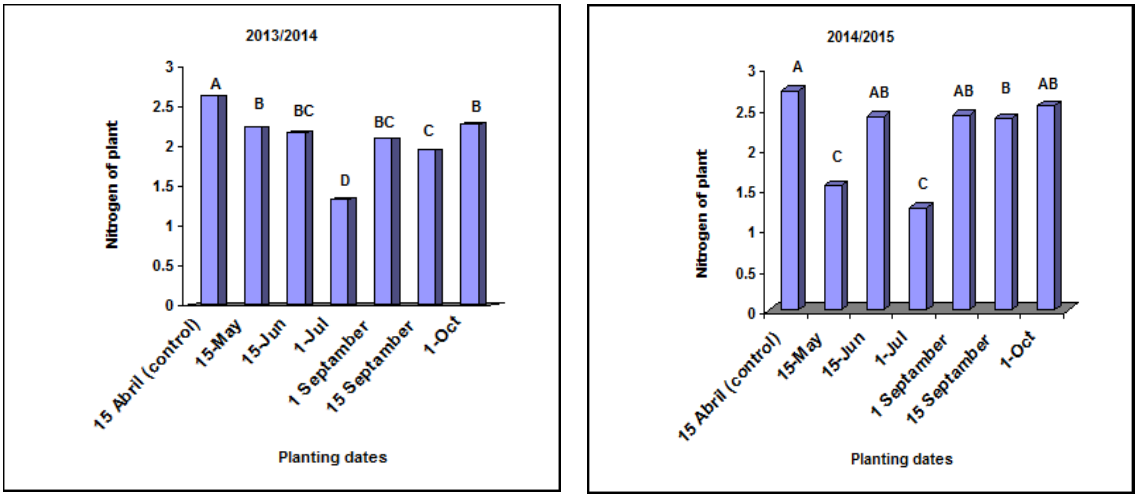

Fig. 1: Effect of planting dates on nitrogen % of Jerusalem artichoke plants in 2013/2014 and 2014 / 2015 seasons.

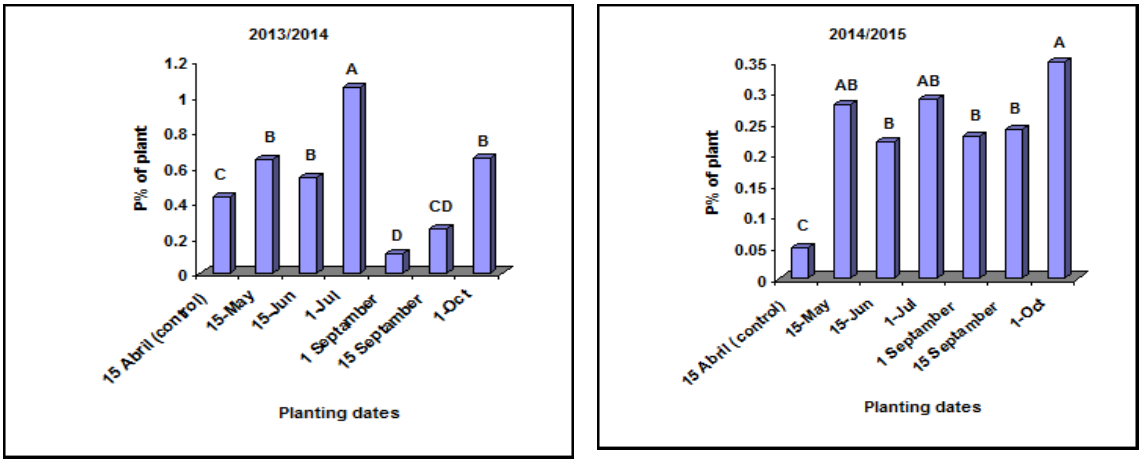

Fig. 2: Effect of planting dates on phosphorus % of Jerusalem artichoke plant in 2013/2014 and 2014/2015 seasons

Concerning phosphorus content of plants in Fig. 2, the data reveal that planting on July 1st significantly increased phosphorus content of plants compared with the other planting dates in the first season. In the second season planting on mid May, July 1st and October 1st gave the highest phosphorus content of plants.

On the other hand, this positive result was reversed with potassium content of plants in Fig. 3. Results indicate that planting on July 1st and October 1st were the best treatments during the two seasons.

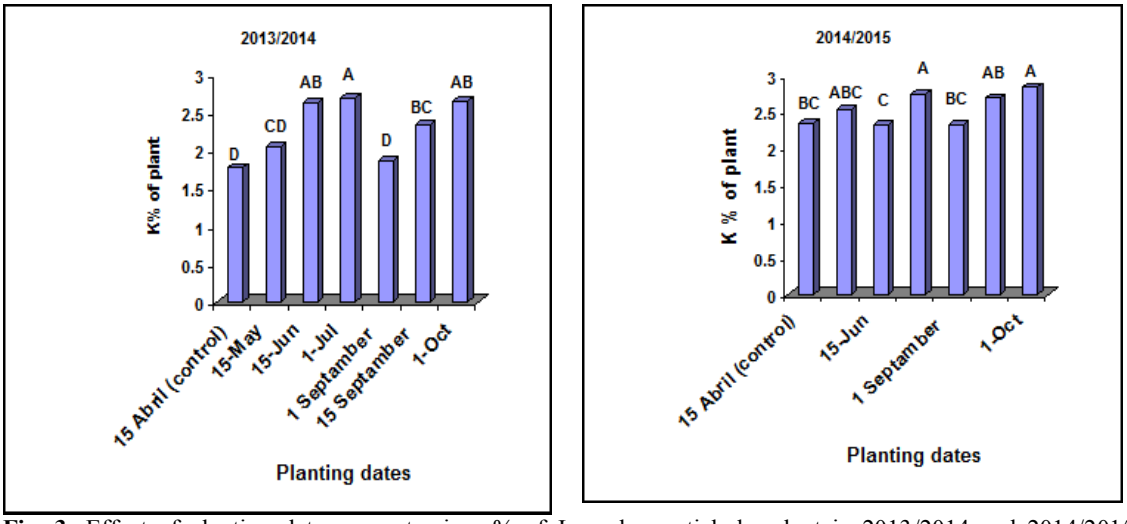

Fig. 3: Effect of planting dates on potassium % of Jerusalem artichoke plant in 2013/2014 and 2014/2015 seasons

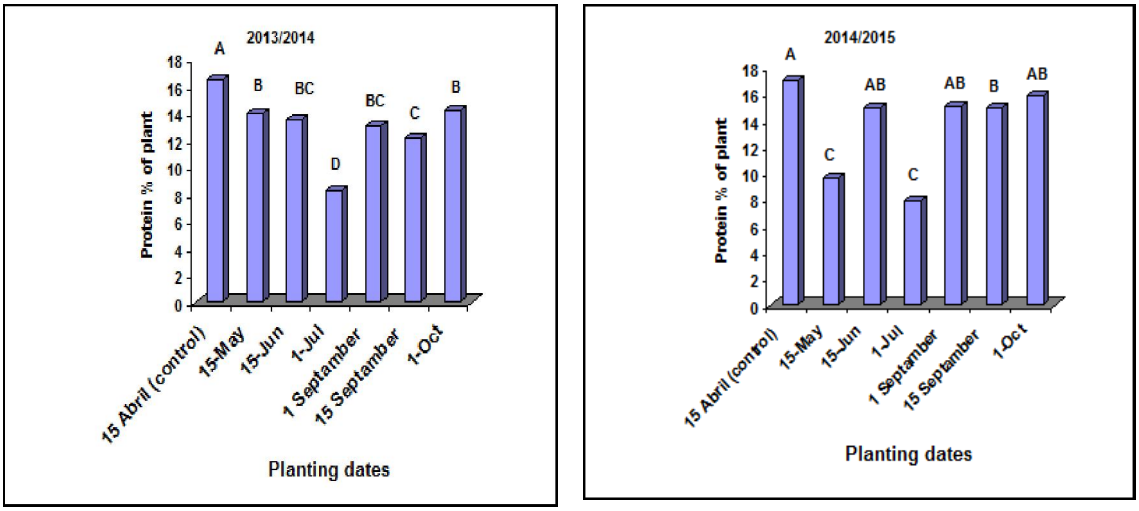

Fig. 4: Effect of planting dates on protein % of Jerusalem artichoke plant in 2013/2014 and 2014/2015 seasons.

Economic evaluation:-

The cost benefit analyses show the trend of Jerusalem artichoke cultivation as influenced by planting dates. The details of economic analysis have been presented in Table (4). The total cost of production ranged between 10200 to 12400 LE. /fed. among the treatment combination, the variation due to different of planting dates. The highest gross return and net return LE./ fed. were achieved from planting on mid April followed by mid May and September 1st in two seasons compared with the other planting dates. Whereas, the lowest value of gross return and net return were obtained from planting in fall season on mid September in both seasons.

Table 4: Costs and net return of Jerusalem artichoke production Influenced by planting dates and seasons treatments.

Treatments	Total cost of Production (L.E/fed.)	Cross return (L.E/fed.)	Net return (L.E/fed.)
		2013/2014	
Mid April (control)	12400	60000	47600
Summer season			
Mid May	11875	44220	11831
Mid June	11350	22040	10690
July1st	11112.5	20620	9508
Fall seasn			
September1st	10750	24420	13670
Mid September	10462.5	17120	6658
October1st	10200	21220	11020
2014/2015			
Mid April (control)	12400	64160	51760
Summer season			
Mid May	11875	46000	34125
Mid June	11350	20640	9290
July 1st	11112.5	35100	23988
Fall season			
September 1st	10750	41820	31070
Mid September	10462.5	19900	9438
October1st	10200	36800	11020

Conclusion

It could be concluded that planting Jerusalem artichoke on mid April and mid May were the best planting dates to enhance plant growth, yield, its components and net return followed by September 1st. On the other hand, the highest values of inulin and carbohydrate contents were found in planting on July 1st, September 1st and mid September as suitable planting dates for tubers processing .

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