RESEARCH ARTICLE

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GENOTYPIC VARIABILITY FOR INULIN CONTENT, TUBER YIELD AND TUBER WEIGHT OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.) GERMPLASM

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SUMMARY

Inulin content is a priority trait in Jerusalem artichoke breeding program. However, breeding for high inulin in Jerusalem has not been reported in the semi-arid tropics. The objective of this study was to evaluate the genotypic variation for inulin content and to the selection of parental line for useful in breeding for high inulin content under different seasons. Development of high inulin content genotypes with high yield and good agronomic traits is required, and it can be improved through breeding. Field experiments were conducted during the late-rainy season from September to December 2014 and early-rainy season from June to September in 2015 at the Field Crop Research Station of Khon Kaen University. A randomized complete block design (RCBD) with two replications was used. Ninety-six Jerusalem artichoke accessions were used in both seasons. Data were recorded on tuber number per plant, fresh tuber yield and inulin content at harvest. The results indicated that Jerusalem artichoke accessions were significantly different for inulin content, tuber number per plant and fresh tuber yield, and there were significant genotype × environment interactions for these traits. However, the interaction between genotype and environment for these traits was low compared to genotype effect. Therefore, the genotype with high inulin content could be identified in this study. HEL 278 had consistently high inulin content and fresh tuber yield across seasons. This genotype could be used to develop high inulin content coupled with high tuber yield in the breeding program. The information on genetic variation in inulin content is useful for selection of parental lines in Jerusalem artichoke breeding program for improvement of inulin content.

Keywords: Sunchoke, fructan, tuber yield, genotypic variation

Key findings: Significantly differences among Jerusalem artichoke accessions were observed for inulin content. HEL 272, HEL 278 and HEL 288 were identified as having high inulin content.

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INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) is an inulin-containing tuber crop. Inulin is well recognized as a prebiotic food, and is also suitable for the patients with diabetes mellitus, high blood pressure and coronary artery disorders as it can reduce serum triglycerides, total cholesterol, LDL and VLDL (Davidson and Maki, 1999; Niness, 1999; Pool-Zobel, 2005; Gaafar *et al*., 2010; Byung-Sung, 2011). Moreover, inulin can increase immunity and reduce the risk for colorectal cancer (Farnworth, 1993; Watzl *et al*., 2005). Prebiotics are non-digestible complex carbohydrates that are fermented in the colon, yielding energy and short chain fatty acids.

Prebiotics are known to selectively promote the growth of Bifidobacteria and Lactobacillae in the gastro-intestinal tract. Inulin and oligofructose have been well-established as prebiotics (Roberfroid, 2007). Many vegetables, root and tuber crops as well as some fruit crops are well-known sources of prebiotic carbohydrates (Schaafsma and Slavin, 2015). Jerusalem artichoke is considered the most promising crop for functional food in the tropics (Puangbut *et al*., 2012). Therefore, a breeding program at Khon Kaen University is being carried out to improve Jerusalem artichoke varieties with high inulin content, high yield, and good agronomic traits.

The information on genetic diversity in Jerusalem artichoke is important and necessary for selection of suitable parental lines in Jerusalem artichoke breeding program for improvement of inulin content. However, the information on genotypic response to different seasons for inulin traits is rather limited and the extent to which the genotypic interact with the seasons has not been adequately researched. The previous study has been evaluated in 79 Jerusalem artichoke accessions and found a significant genetic variation for inulin content (Puttha *et al*., 2012). High interactions between genotype and environment (G × E) were observed for inulin content and multi-location trials are necessary to identify the best genotypes. Furthermore, the information on the variation in inulin content in a large number of Jerusalem artichoke accessions is rather limited researched. The objective of this study was to evaluate the genotypic variation for inulin content and to the selection of parental line for useful in breeding for high inulin content under different seasons.

MATERIALS AND METHODS

Plant materials and experimental design

Ninety-six Jerusalem artichoke accessions used in this study were donated from three institutions (Table 1). One accession from the North Central Regional Plant Introduction Station (NCRPIS), 71 accessions from the Plant Gene Resource of Canada (PGRC), 22 accessions from the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) of Germany and two accessions from Thailand (KT 50-4 is a hybrid clone).

Ninety-six accessions of Jerusalem artichoke were evaluated in field experiments during the late-rainy season from September to December 2014 and early-rainy season from June to September in 2015 at the Field Crop Research Station of Khon Kaen University. A randomized complete block design with two replications was used. Plot size was 1.6 × 5 m with a spacing of 50 cm between rows and 40 cm between hills in a row.

Crop management

The soil was ploughed once using a 3-disc tractor and twice using a 7-disc tractor and ridged at a distance of 2 m. Then, the ridges were leveled to make soil beds.

Seed tubers were cut into small pieces each of which had two or three buds. The tuber pieces were incubated in plastic bags containing moist coconut peat at the bottom and the top of the bags for 7 days under ambient conditions. The plastic bags were kept open for good aeration. The tuber pieces with active buds and roots were further transferred to germinating plug trays with mixed medium containing burnt rice husk and soil for 7 days for complete sprouting. The fourth leaf-sprouted (V4) seedlings were then suitable for transplanting in the plot (Puangbut *et al*., 2015a). One seedling was transplanted per hill. Fertilizer formula 15-

15-15 was applied at 30 days after transplanting (DAT) at a rate of 156 kg per ha^{-1}. Supplementary irrigation was applied to the crop with an overhead sprinkler system at two-day intervals.

Table 1. Jerusalem artichoke accessions, sources of origin and genetic resources.

Entry No.	Accession No.	Name of accession	Genetic resources*	Origin
1	JA 1	7305	PGRC	Canada
2	JA 2	7306	PGRC	Canada
3	JA 6	7310	PGRC	Canada
4	JA 7	7312	PGRC	Canada
5	JA 8	7512	PGRC	Canada
6	JA 9	7513	PGRC	Canada
7	JA 10	HM Hybrid A	PGRC	Canada
8	JA 12	HM Hybrid C	PGRC	Canada
9	JA 14	HM–3	PGRC	Canada
10	JA 15	HM–5	PGRC	Canada
11	JA 16	HM–7	PGRC	Canada
12	JA 18	HM–9	PGRC	Canada
13	JA 20	HM–11	PGRC	Canada
14	JA 23	DHM–3	PGRC	Canada
15	JA 35	W–97	PGRC	Canada
16	JA 36	W–106	PGRC	Canada
17	JA 46	DHM–14–3	PGRC	Canada
18	JA 47	DHM–14–6	PGRC	Canada
19	JA 58	Intress	PGRC	USSR
20	JA 59	Volzskij–2	PGRC	USSR
21	JA 60	Jamcovskijkrashyj	PGRC	USSR
22	JA 71	TUB–675 USD–ARS–SR	PGRC	USA
23	JA 72	TUB–676 USD–ARS–SR	PGRC	USA
24	JA76	#4	PGRC	Canada
25	JA 77	#5	PGRC	Canada
26	JA 93	Leningradskii (NC10–65)	PGRC	USSR
27	JA 108	83-001-3 (37 × 6)	PGRC	Canada
28	JA 109	83-001-4 (37 × 6)	PGRC	Canada
29	JA 114	83-001-9 (37 × 6)	PGRC	Canada
30	JA 122	83-004-2 (6 × 20)	PGRC	Canada
31	JA 132	83-007-2 (69 × 3)	PGRC	Canada
32	KKU Ac 001	Unknown	Unknown	Thailand
33	CN 52867	PGR–2367	PGRC	USSR
34	JA 37	Comber	PGRC	Canada
35	JA 38	B.C. #1	PGRC	Canada
36	JA 67	Oregon White	PGRC	USA
37	JA 89	Waldspindel	PGRC	France
38	JA 102	073–87	PGRC	Germany
39	HEL 53	–	IPK	Germany
40	HEL 61	TambovskijKrasnyi	IPK	Russian Federation
41	HEL 62	SachalinskijKrasnyi	IPK	Russian Federation
42	HEL 65	Sejanec 19	IPK	Russian Federation
43	HEL69	–	IPK	Unknown
44	HEL 231	–	IPK	Germany
45	HEL 335	–	IPK	Unknown
46	Ames 2729	TUB–49	NCRPIS	South Dakota
47	HEL 243	Bianka	IPK	Germany
48	HEL 246	–	IPK	Unknown

(cont'd)

Table 1. Jerusalem artichoke accessions, sources of origin and genetic resources.

Entry No.	Accession No.	Name of accession	Genetic resources*	Origin
49	HEL 248	Rote Zonenkugel	IPK	Germany
50	HEL 253	–	IPK	Unknown
51	HEL 256	–	IPK	Unknown
52	HEL 257	BT4	IPK	Unknown
53	HEL 265	D19–63–340	IPK	Hungry
54	HEL272	Voelkenroder	IPK	France
55	HEL278	Spindel	IPK	Unknown
56	HEL 280	RA1	IPK	Unknown
57	HEL288	RA9	IPK	Poland
58	HEL 293	–	IPK	Poland
59	HEL 308	–	IPK	Unknown
60	HEL 316	–	IPK	Unknown
61	HEL 317	–	IPK	Unknown
62	KT 50-4	[JA 102 × JA 89]-8	KKU	Thailand
63	JA 19	HM-10	PGRC	Canada
64	JA 22	HM-13	PGRC	Canada
65	JA 27	DHM-7	PGRC	Canada
66	JA 49	7513A	PGRC	Canada
67	JA 95	NACHODKA	PGRC	USSR
68	JA 98	242-62	PGRC	France
69	JA 99	29-65	PGRC	France
70	JA 107	83-001-2 (37 X 6)	PGRC	Canada
71	JA 111	83-001-6 (37 X 6)	PGRC	Canada
72	JA 113	83-001-8 (37 X 6)	PGRC	Canada
73	JA 116	83-001-11 (37 X 6)	PGRC	Canada
74	JA 119	83-002-1 (69 X 6)	PGRC	Canada
75	JA 125	83-005-1 (39 X 40)	PGRC	Canada
76	JA 127	83-005-2 (39 X 40)	PGRC	Canada
77	JA 129	83-006-1 (40 X 39)	PGRC	Canada
78	JA 130	83-006-4 (40 X 39)	PGRC	Canada
79	JA 133	83-001-11 (37 X 6)	PGRC	Canada
80	JA 134	83-002-1 (69 X 6)	PGRC	Canada
81	JA 135	83-005-1 (39 X 40)	PGRC	Canada
82	JA 21	HM-12 Canada PGRC	PGRC	Canada
83	JA 3	7307	PGRC	Canada
84	JA 123	–	PGRC	Canada
85	JA 86	–	PGRC	France
86	HEL 68	–	PGRC	Unknown
87	JA 55	–	PGRC	USA
88	JA 81		PGRC	France
89	JA 4	7308	PGRC	Canada
90	JA 5	7309	PGRC	Canada
91	JA 117	–	PGRC	Canada
92	JA 61	Vadim	PGRC	USSR
93	JA 11	HM Hybrid B	PGRC	Canada
94	JA 97	D19-63-340	PGRC	France
95	HEL 66	KievskijBelyj	PGRC	Ukraine
96	JA 120	83-003-1 (6 9 20)	PGRC	Canada

*NCRPIS = The North Central Regional Plant Introduction Station; IPK = The Leibniz Institute of Plant Genetics and Crop Plant Research; PGRC: Plant Gene Resources of Canada; KKU = Khon KaenUniversity

Data collection

Weather conditions

Weather data were recorded. The seasonal mean of maximum temperature in the late-rainy season was 32.0 ºC and minimum temperature was 21.0 °C (Figure 1). The mean of maximum temperature in the early-rainy seasons was 35.2 ºC and minimum temperature was 25.0 °C (Figure 2). The means of solar radiation in the late-rainy season were 17.9 MJ m^{-2} d^{-1} (Figure 1) and it was 17.8 MJ m^{-2} d^{-1} in the early-rainy season (Figure 2). Rainfalls in the late-rainy seasons were 211.7 mm (Figure 1) and it was 665 mm in the early-rainy season (Figure 2).

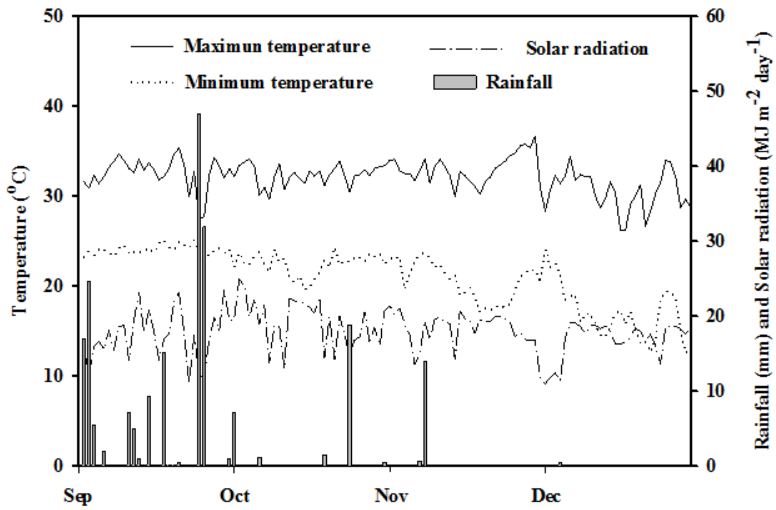

Figure 1. Daily maximum temperature, minimum temperature, solar radiation and rainfall during the late-rainy 2014 at Khon Kaen University, Khon Kaen, Thailand.

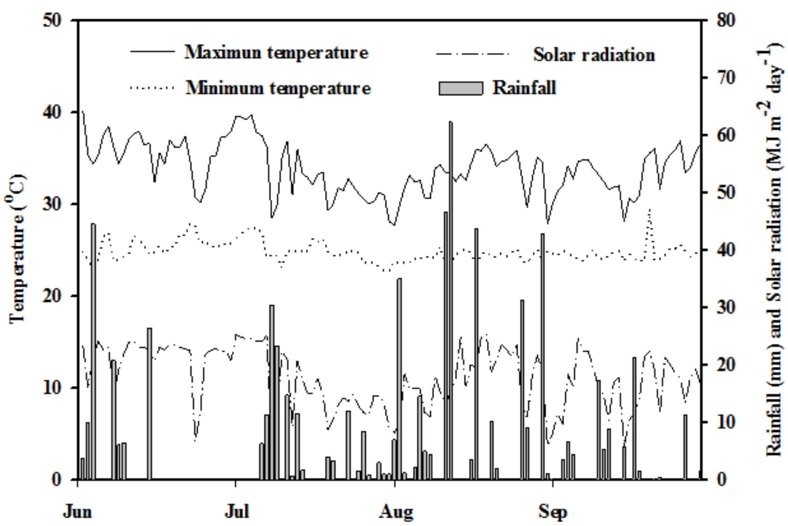

Figure 2. Daily maximum temperature, minimum temperature, solar radiation and rainfall during the early-rainy season 2015 at Khon Kaen University, Khon Kaen, Thailand.

The growing conditions were different between seasons and this could be due to the difference in temperatures. The results indicated that solar radiation is not a significant different between late-rainy and early-rainy seasons. Rainfall well distributed throughout the crop cycle in the early-rainy seasons. However, no water stress was observed during the growing season for late-rainy seasons.

Fresh tuber yield and number of tuber per plant

At harvest, plants at the end of the rows and border rows were discarded. Then, 16 plants in an area of 3.2 m^2were harvested. Plants were cut at the soil surface and separated into shoots and tubers. Tubers were washed in tap water to remove the potting medium and then tuber fresh weight was determined. Three plants in each plot were sampled randomly and used for determination of number of tubers per plant.

Inulin content

Inulin content was analyzed using the methods described by Saengkanuk *et al*. (2011). Briefly, the tubers were longitudinally sliced into thin pieces at the middle part of the tubers. Fifty grams of sliced tuber was soaked in absolute ethanol at 4 °C for 24 h then the samples were stored at -20 °C until analyzed. The samples were oven dried at 60 °C for 10 hours. To extract inulin, 2 g of dried sample was mixed with distilled water at 80 °C for 20 minutes. The solution was cooled to room temperature and filtered through a 0.45 μm membrane filter. The extracts (500 μl) were pipette into 25 ml volumetric flasks containing 3% HCl and diluted to 25 ml with water. The mixtures were then heated at 80 °C in a water-bath for 45 minutes. After cooling, the solutions were stored in plastic bottles before being analyzed by the spectrophotometer. Inulin analysis was shown as a percentage of inulin content on a dry weight basis.

Statistical analysis

Analysis of variance was performed for individual seasons and error variances were tested for homogeneity by Bartlett's test (Hoshmand, 2006). Because of, genotype × seasons interaction were significant for all characters (Table 2), data were reported for individual seasons. Duncan's multiple range tests (DMRT) was used to compare means within genotypes. Calculations procedures were done using MSTAT-C package (Bricker, 1989).

RESULTS

Genotypic variability and genotype x **environment interactions**

Significant differences between seasons (S) were observed for inulin content, tuber number and fresh tuber yield and significant differences among Jerusalem artichoke genotypes (G) were observed for all traits (Table 2).

Seasons contributed to a small portion of total variation for inulin content (21.2%), tuber number (0.68%) and fresh tuber yield (36.2%).Similar, the interactions between genotype and season contributed to medium portions of variations inulin content (34.1%), tuber number (25.6%) and fresh tuber yield (14.4%). The contribution of genotype was higher than that season for tuber number (60.2%) and fresh tuber yield (40.4%) and genotype contributed to medium for inulin content (35.2%).

Genotypic variations in inulin content, tuber number and fresh tuber yield

There were significant differences among Jerusalem artichoke accessions for inulin content, fresh tuber yield and tuber number in both seasons. The crop grown in the late-rainy season had higher inulin content and fresh tuber yield than did the crop grown in the early-rainy season (Table 3).

In the late-rainy season, the genotype with high or low inulin could be identified and the accessions were then divided into two extreme groups each of which has ten accessions (Table 4). JA 95, HEL 308, JA 98, HEL 278, HEL 293, HEL 272, HEL 288, JA 125, JA 10 and JA 36 were identified as having high inulin content ranged from 73.6-76.6% of dry weight.

Table 2. Mean squares from combined analysis of variance for inulin content, number of tuber per plant and fresh tuber yield of 96 Jerusalem artichoke accessions observed in the early-rainy season 2015 and late-rainy season 2014/15.

Source of variation	df	Inulin content	Number of tuber	Fresh tuber yield
Season (S)	1	5985.83(21.2)*	364.260 (0.68)*	1.700E+08(36.2)*
Rep. within S	2	30.73	341.354	5194217
Clone/genotype (G)	95	104.95(35.2)**	339.447(60.2)**	1996981(40.4)**
G × S	95	101.65(34.1)**	144.297(25.6)**	712130(14.4)**
Pooled error	190	13.80	34.623	166802
Total	383			

*, ** Significant at $P < 0.05$ and significant at $P < 0.01$
Numbers within the parentheses are percentages of sum squares to total sum of squares.

Table 3. Inulin content, number of tuber and fresh tuber yield for averaged over 96 Jerusalem artichoke accessions.

Seasons	Inulin content (% of dry wt)	Number of tuber (tuber plant^{-1})	Fresh tuber yield (kg ha^{-1})
Late-rainy season	61.5 ± 6.1 a	32.0 ± 8.4	2553 ± 230 a
Early-rainy season	54.0 ± 5.7 b	30.3 ± 5.6	1228 ± 280 b
F-test	**	ns	**

Data are presented as mean ± SD ($n = 2$)
Means in the same column with the different letters are significantly different by DMRT ($P < 0.05$).
ns; non-significant, ** Significant at $P < 0.01$

The low group comprised of HEL 243, HEL 253, HEL 53, HEL 69, HEL 248, JA 76, JA 97, HEL 231, JA 8 and HEL 335 with the range of 42.5-50.6%. The ranks in the two groups were not overlapped and statistically different, and, therefore, the genotypes with low and high inulin content were readily identified.

Tuber number of the high group ranged between 15.5-49.0 tubers per plant **(**Table 4**).** The ranges between high and low groups were overlapped. A wide range of fresh tuber yield was observed among Jerusalem artichoke accessions within the high group, ranging from 11,500 to 28,500 kg ha^{-1} (Table 4). However, the ranks of high and low groups were overlapped. HEL 278, HEL 272 and HEL 288 could be identified as inulin content combined with high fresh tuber yield.

In the early-rainy season, the genotype with high or low inulin could be identified and the accessions were then divided into two extreme groups (Table 5). JA 22, HEL 278, JA 61, HEL 288, HEL 62, HEL 272, HEL 256, Ames 2729, JA 19 and HEL 316 were identified as having high inulin content ranged from 61.3-75.0% of dry weight (Table 5). The low group comprised of HEL 69, JA 55, JA 117, JA 135, JA 49, JA 76, JA 111, HEL 68, JA 11 and JA 102 with the range of 39.3-47.1% of dry weight (Table 5). The ranks in the two groups were not overlapped and statistically different, and, therefore, the genotypes with low and high inulin content were readily identified.

Tuber number of high group ranged between 18.0-39.0 tubers per plant **(**Table 5**).** The ranges between high and low groups were overlapped. A wide range of tuber yield was observed among Jerusalem artichoke accessions within high group, ranging from 3,118 to 11,718 kg ha^{-1}(Table 5). However, the ranks of high and low groups were overlapped. However, the genotype with high inulin content coupled with high fresh tuber yield was observed in HEL 278, HEL 272, HEL 288 and JA 22.

Table 4. Inulin content tuber number and fresh tuber yield of 96 Jerusalem artichoke in late- rainy season 2014/15.

Groups	Entry no.	Genotypes	Inulin content (% of dry wt)	Tuber no. (tuber plant^{-1})	Fresh tuber yield (kg ha^{-1})
High	67	JA 95	76.6 ± 2.7 a	22.5 ± 5.7 f-z	1,800 ± 40 g-s
	59	HEL 308	76.3 ± 1.7 a	20.5 ± 0.5 w-z	17,250 ± 40 i-u
	68	JA 98	76.1 ± 0.2 a	31.5 ± 7.5 l-x	17,750 ± 40 h-s
	55	HEL 278	75.8 ± 1.2 ab	24.0 ± 1.2 s-z	28,500 ± 360 abc
	58	HEL 293	75.6 ± 0.8 ab	23.5 ± 5.5 s-z	11,500 ± 220 u-z
	54	HEL 272	74.9 ± 0.2 abc	31.5 ± 1.3 l-x	20,500 ± 280 e-m
	57	HEL 288	74.4 ± 4.1 a-d	34.0 ± 4.3 j-v	21,000 ± 260 e-k
	75	JA 125	74.3 ± 3.2 a-d	28.5 ± 3.3 n-z	15,500 ± 200 k-w
	7	JA 10	73.9 ± 6.7 a-e	15.5 ± 3.5 c-n	24,750 ± 200 a-e
	16	JA 36	73.6 ± 1.0 a-f	49.0 ± 4.0 c-k	12,750 ± 40 q-z
Low	47	HEL 243	50.6 ± 1.4 ab	24.0 ± 2.0 s-z	22,000 ± 120 d-j
	50	HEL 253	49.4 ± 2.6 abc	26.5 ± 1.7 p-z	14,250 ± 120 n-y
	43	HEL 53	48.7 ± 1.3 abc	26.5 ± 0.5 q-z	23,500 ± 120 e-m
	39	HEL 69	48.7 ± 0.1 abc	25.5 ± 1.5 p-z	20,250 ± 240 c-h
	49	HEL 248	48.5 ± 1.4 abc	21.0 ± 1.2 v-z	21,000 ± 240 e-l
	38	JA 76	48.3 ± 1.8 abc	24.5 ± 5.8 r-z	28,250 ± 120 abc
	94	JA 97	47.8 ± 0.9 abc	41.0 ± 5.3 d-o	18,000 ± 400 g-s
	44	HEL 231	47.7 ± 0.8 abc	19.5 ± 2.2 xyz	17,750 ± 280 h-s
	5	JA 8	46.5 ± 3.6 bc	54.0 ± 0.8 abc	9,250 ± 40 xyz
	45	HEL 335	42.5 ± 2.6 c	32.0 ± 4.0 k-x	15,250 ± 280 l-x
Max			76.6	60.5	29,750
Min			42.5	9.5	3,000
Mean			61.9 ± 6.1	32.0 ± 8.4	15,956 ± 732
F-test			**	**	**

Data are presented as mean ± SD ($n = 2$), minimum, maximum and mean values were calculated from 96 accessions
Means in the same column with the same letters are not significantly different by DMRT ($P < 0.05$).
** Significant at $P < 0.01$ probability level

DISCUSSION

The selection for high tuber yield and inulin content are priorities of Jerusalem artichoke breeding programs. Variation in genotype and environments can affect inulin content and tuber yield of Jerusalem artichoke. However, there is limited information on the variation in inulin content in a large number of Jerusalem artichoke accessions. Furthermore, information of genotypic response for inulin content to different environments is important for breeding programs. However, there was a few information on genotype, season and genotype × season interaction for inulin content.

This study revealed a significant genotypic variation for inulin content which could potentially be exploited in Jerusalem artichoke breeding programs. High genetic variation was found for inulin content and selection for this character is possible. The results also demonstrated that contribution of genotype was higher than that season for inulin content and fresh tuber yield. Similar to previous studies reported that genotypic contributed to a large portion of variation in fresh tuber yield and inulin content (Puangbut *et al*., 2011; Puttha *et al*., 2012; Puangbut *et al*., 2015c). A large estimate of genetic variance indicates that selection and breeding initiatives can proceed in this study.

Over all genotypes, inulin content in the late-rainy season was higher than that in the early-rainy season, while tuber number showed no significant differences between seasons. Contrast to previous studied reported that crop grown in the early-rainy season had higher inulin content than did the crop grown in the late-rainy season (Puangbut *et al*., 2015c).

Table 5. Inulin content tuber number and fresh tuber yield of 96 Jerusalem artichoke in early- rainy season 2015.

Groups	Entry no.	Genotypes	Inulin content	Tuber no. (tuber plant^{-1})	Fresh tuber yield (kg ha^{-1})
High	64	JA 22	75.0 ±8.3 a	39.0 ± 5.8 a-m	9,462 ± 220 b-t
	55	HEL 278	64.9 ± 6.1 b	20.0 ± 5.4 r-z	11,718 ± 200 a-k
	92	JA 61	64.4 ± 5.4 bc	36.0 ± 1.1 b-r	4,925 ± 7.3 i-x
	57	HEL 288	64.2 ± 1.3 bc	31.0 ± 3.2 f-x	8,818 ± 11 c-u
	41	HEL 62	64.0 ± 0.7 bcd	18.0 ± 4.2 u-z	6,365 ± 116 g-x
	54	HEL 272	64.0 ± 3.9 bcd	37.5 ± 0.9 b-0	9,138 ± 71 b-u
	51	HEL 256	62.7 ± 1.9 b-e	34.0 ± 3.9 c-u	6,594 ± 78 f-x
	46	Ames 2729	62.4 ± 4.3 b-f	32.0 ± 4.8 e-w	3,118 ± 178 p-x
	63	JA 19	61.8 ± 5.7 b-g	26.5 ± 1.6 i-z	5,906 ± 105 g-x
	60	HEL 316	61.3 ± 3.9 b-h	23.5 ± 0.8 m-z	5,644 ± 162 g-x
Low	43	HEL 69	47.1 ± 5.7 p-w	20.0 ± 1.3 r-z	6,144 ± 41 g-x
	87	JA 55	47.1 ± 2.8 p-w	30.5 ± 2.5 g-z	7,931 ± 53 c-x
	91	JA 117	46.9 ± 5.2 q-w	35.5 ± 4.5 b-s	4,494 ± 92 l-x
	81	JA 135	46.6 ± 0.7 r-w	34.0 ± 2.3 c-u	10,025 ± 60 b-p
	66	JA 49	46.1 ± 3.3 r-w	31.0 ± 4.4 f-x	2,793 ± 6.8 r-x
	24	JA 76	45.0 ± 2.7 t-w	13.0 ± 4.1 z	5,931 ± 144 g-x
	71	JA 111	44.9 ± 4.7 t-w	28.0 ± 6.3 i-z	6,981 ± 101 e-x
	86	HEL 68	43.1 ± 0.7 uvw	24.5 ± 0.7 k-z	8,406 ± 64 c-x
	93	JA 11	41.6 ± 0.8 vw	29.0 ± 6.5 h-z	8,700 ± 28 c-w
	38	JA 102	39.3 ± 3.6 w	24.5 ± 2.7 k-z	8,287 ± 233 c-w
Max			75.0	54.5	17,968
Min			39.3	11.5	1,487
Mean			54.0 ± 4.4	30.3 ± 6.1	7,675 ± 303
F-test			**	**	**

Data are presented as mean ± SD (n = 2), minimum, maximum and mean values were calculated from 96 accessions
Means in the same column with the same letters are not significantly different by DMRT (P < 0.05).
** Significant at P < 0.01 probability level

The differences in the results may be due to the differences in the plant materials and climatic factors such as temperature.

The results also indicated that the crop grown in the late-rainy season had higher fresh tuber yield than did the crop grown in the early-rainy. This study supported previous findings that Jerusalem artichoke grown in the late-rainy season produced higher tuber yield (Puangbut *et al*., 2012; Puangbut *et al*., 2015b, 2015c; Ruttanaprasert *et al*., 2013).This could be due to the vegetative growth was declined in the late-rainy season but induce high partitioning of assimilates from temporary sink to tuber and resulted in high tuber yield (Puangbut *et al*., 2015c; Rattanaprasert *et al*., 2013; Somda *et al*., 1999).

This result indicated that there was a possibility to select Jerusalem artichoke with high inulin content and high fresh tuber yield. The relationship between inulin content and fresh tuber yield were positive and significant. High correlation between inulin content and fresh tuber yield was found in the early-rainy season (r = 0.75*) and in the late-rainy season (r = 0.60*) (data not presented). Similar to the previous study indicated that inulin content was associated with fresh tuber yield (Puttha *et al*., 2012). HEL 278 showed consistently high inulin content and fresh tuber yield across seasons. This genotype could use as parental lines in Jerusalem artichoke breeding program for improvement of inulin content combined with high tuber yield, based on presented data on Tables 4-5.

CONCLUSION

Jerusalem artichoke accessions have high variations in inulin content and fresh tuber yield and then selection for these characters is possible among these accessions. Genotype with high inulin content and fresh tuber yield could be identified among these accessions. Over both seasons, HEL 272, HEL 278 and HEL 288 had consistently high inulin content. These accessions can be used as sources of high inulin genotype for useful in the breeding program for high inulin content.

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