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VARIABILTY AND STABILTY OF TUBER YIELD OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.)

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SUMMARY

The objective of this paper was to estimate the genetic and ecological variation as well as the stability of tuber yield per plant, tuber number per plant and tuber size of Jerusalem artichoke based on the results of a variety trial carried out with 20 different Jerusalem artichoke varieties during the period of 1994-2000. Significant genetic as well as ecologycal variation was observed for all of the traits studied. The most promissing varieties showing high tuber yield combined with high yield stability were "BT-4", "Violet Rennes" and "UKR 4/82". It is encouraging that the highest yielding varieties exibited a rather stable performance over environments.

Key words: **ecological variation, genetic variation, *Helianthus tuberosus* L., Jerusalem artichoke, tuber yield, yield stability**

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) is a widespread crop presented mostly by local populations in Yugoslavia (Dozet *et al.*, 1993; Ristić, 1954). Along with traditional ways of its utilization as a poor-man's food (Boswell, 1959), this crop is attracting an increasing attention due to the high proportion of fructose in the tubers (Pilnik and Vervelde, 1976). The objective of numerous successfull studies was to use Jerusalem artichoke as an "energy crop" for bioalcohol production (Berenji and Kovač, 1983; Kišgeci *et al.*, 1988). Analytical procedures along with the optimization of the process of bioethanol production from Jerusalem artichoke tubers were studied in detail (Pejin *et al.*, 1991; 1993). Jerusalem artichoke is also successfully used in sunflower (*Helianthus annuus* L.) breeding program as a source of disease resistance genes (Škorić and Vanozzi, 1984; Thompson *et al.*, 1981).

This paper as part of the research activities on Jerusalem artichoke breeding and cultural practices carried out at the Institute of Field and Vegetable Crops in Novi Sad (Yugoslavia) is an attempt to describe the results of a long-term variety

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trial based on different Jerusalem artichoke varieties in order to determine the genetic and ecological variation as well as the stability of tuber yield.

MATERIALS AND METHODS

Variety trials were carried out at the Institute of Field and Vegetable Crops in Novi Sad, *i.e.*, at the experiment fields located in Bački Petrovac on a chernozem soil during the period 1994-2000 using 20 varieties of Jerusalem artichoke (Table 1, Figure 1).

Table 1: Jerusalem artichoke varieties tested

Number	Variety	Origin of the variety
1	UKR 1/82	Half-sib progenies obtained by crossing and maintained by vegetative propagation at the Institute of Field and Vegetable Crops, Novi Sad, Yugoslavia
2	UKR 2/82	
3	UKR 4/82	
4	UKR 5/82	
5	UKR 6/82	
6	B. Koviljaèa	
7	Violet Communes	I.N.R.A. Station d'Amélioration des Plantes, Le Rheu, France
8	Violet Rennes	
9	Topianca	
10	Fuseau 60	
11	Ozor	
12	D - 19	
13	K-8	
14	207-63	
15	952-63	
16	Waldspindel D	Institut für Pflanzenbau und Pflanzenzüchtung, Braunschweig, Germany
17	Waldspindel A	Zuckerforshung-Institut, Fuchsenbigl, Austria
18	Bela	Univerza Ljubljana, Biotehniška fakulteta, Ljubljana, Slovenia
19	BT - 3	Agrobotanikai Központ, Tápiószele, Hungary
20	BT - 4	

One row per genotype consisting of 20 plants each with border plants around the experiment was planted early in the spring using medium size tubers derived from the harvest of the experiment planted the previous year by inserting one tuber per hole dug by hand to cca 10 cm depth and covered by soil immediately after. The planting pattern of 100 x 50 cm resulted in plant density of 20000 plants/ha. Standard production technology was applied during the vegetation (Le Cochec, 1981; Berenji, 1994). The aboveground part of the plants was removed after the first frost in the autumn. Early in the next spring, 5 selected, average-performing plants considered as replications were harvested by hand. The tuber mass per plant has been measured in kg/plant and the number of tubers per plant was counted. The average

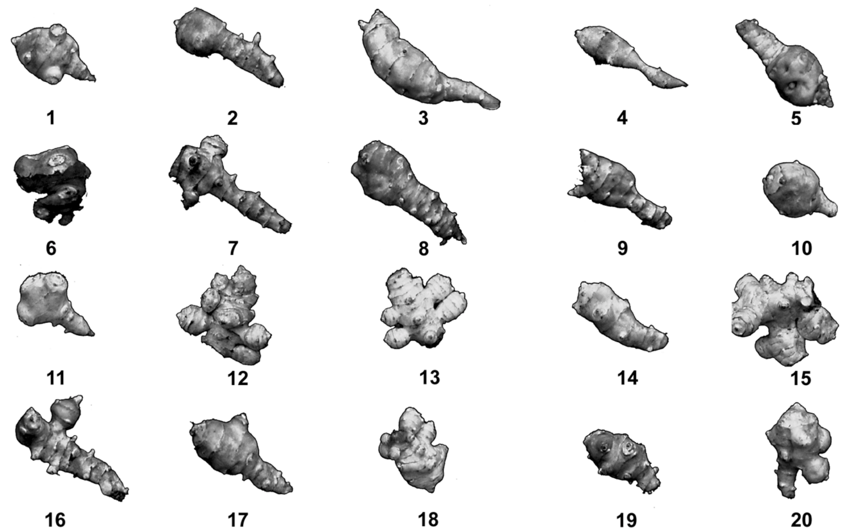

Figure 1: Tubers of the 20 Jerusalem artichoke cultivars studied. The designations correspond to the ordinal numerals in Tables 1-4.

Table 2: Tuber yield per plant (kg) of the Jerusalem artichoke varieties tested

Number	Variety	Year								Average	Rank
		1994	1995	1996	1997	1998	1999	2000	2001		
1	UKR 1/82	2.89	2.85	2.29	2.15	1.78	2.52	1.49	2.09	2.25	12
2	UKR 2/82	4.27	1.46	1.47	1.22	0.69	1.52	2.18	0.74	1.69	18
3	UKR 4/82	4.03	2.49	2.94	2.98	2.37	2.88	2.39	1.79	2.73	6
4	UKR 5/82	2.13	1.25	1.27	1.90	1.24	2.45	0.99	1.50	1.59	19
5	UKR 6/82	3.71	3.52	2.56	3.17	1.55	2.48	3.55	1.44	2.74	5
6	B. Koviljača	1.56	1.81	0.76	2.55	1.48	3.38	2.50	1.83	1.98	16
7	Violet Communes	3.21	2.41	1.92	2.13	1.30	1.75	2.10	1.83	2.08	14
8	Violet Rennes	2.89	3.16	2.65	4.88	2.54	3.01	2.28	2.60	3.00	2
9	Topianca	3.87	1.97	1.34	2.43	1.29	2.39	2.27	1.04	2.06	15
10	Fuseau 60	3.35	2.28	1.23	2.63	1.26	2.48	3.50	1.52	2.28	11
11	Ozor	3.86	2.67	2.62	3.01	1.47	3.63	1.78	2.97	2.75	4
12	D - 19	2.49	2.14	2.44	2.42	1.81	2.49	2.71	2.60	2.39	9
13	K-8	2.62	1.63	2.11	3.66	1.75	2.85	2.48	2.24	2.41	8
14	207-63	2.65	0.86	1.11	1.63	1.03	1.30	0.88	1.20	1.33	20
15	952-63	2.65	1.85	2.29	1.76	1.50	1.97	2.31	2.75	2.13	13
16	Waldspindel D	3.26	2.85	2.46	2.15	2.25	3.71	1.66	1.27	2.45	7
17	Waldspindel A	4.03	3.37	2.23	3.70	1.25	1.72	1.26	1.12	2.33	10
18	Bela	2.33	2.14	2.11	1.85	1.24	2.77	1.03	1.84	1.91	17
18	BT - 3	2.78	3.06	2.38	3.67	2.53	4.01	2.18	2.41	2.88	3
20	BT - 4	4.36	3.37	2.38	4.86	2.43	4.01	3.06	4.29	3.59	1
Average		3.15	2.36	2.03	2.74	1.64	2.67	2.13	1.95	2.33	

LSD at $P<0.01$ probability level between varieties = 0.77;
between years = 0.49; between indivudual cells = 1.09

tuber size for each individual plant was calculated dividing the tuber mass per plant by the number of tubers per plant.

Standard procedures of analsys of variance (ANOVA) was performed and stability parameters calculated using the Eberhart and Russel (1966) model.

RESULTS AND DISCUSSION

The Jerusalem artichoke varieties tested showed a significant variation for tuber yield per plant being in the range of 1.33-3.59 kg/plant (Table 2) which corresponds to 26.6-71.8 t/ha. The average of the whole experiment was 2.33 kg/plant which is 46.6 t/ha. Such yield results correspond to the yield figures published elsewere (Küppers-Sonnenberg, 1965; Le Cochec, 1981; Kovač *et al.*, 1982). The best performing varieties were "BT-4", "Violet Rennes", "BT-3", "Ozor", "UKR 6/82" and "UKR 4/82". Considerable variation was observed between individual years, the highest yielding year (1994) being twice as abundant as the poorest one (1998).

Table 3: Tuber number per plant of the Jerusalem artichoke varieties tested

Number	Variety	Year								Average	Rank
		1994	1995	1996	1997	1998	1999	2000	2001		
1	UKR 1/82	59	43	52	54	58	51	31	35	48	3
2	UKR 2/82	64	26	39	34	24	32	53	16	36	15
3	UKR 4/82	64	24	39	32	42	33	42	25	38	12
4	UKR 5/82	52	31	35	35	33	40	33	23	35	16
5	UKR 6/82	67	64	54	59	38	32	65	27	51	2
6	B. Koviljača	24	23	12	33	17	26	22	24	23	20
7	Violet Communes	57	44	48	33	32	29	37	25	38	11
8	Violet Rennes	32	34	29	46	35	31	22	21	31	18
9	Topianca	67	38	29	34	32	36	37	20	37	14
10	Fuseau 60	71	42	26	48	28	39	53	27	42	7
11	Ozor	59	32	41	44	32	47	35	40	41	8
12	D - 19	52	34	45	31	40	34	41	39	39	9
13	K-8	47	22	32	53	41	42	36	38	39	10
14	207-63	67	19	29	33	23	19	17	21	29	19
15	952-63	75	32	61	33	40	39	39	43	45	5
16	Waldspindel D	56	38	46	41	56	69	29	21	44	6
17	Waldspindel A	59	48	45	50	30	27	21	18	37	13
18	Bela	41	32	35	34	34	33	22	28	32	17
18	BT - 3	62	67	48	70	69	72	31	51	59	1
20	BT - 4	56	48	28	62	42	47	40	54	47	4
Average		56	37	39	43	37	39	35	29	40	

LSD at P<0.01 probability level between varieties = 13; between years = 8;
between indivudual cells = 19

The average number of tubers per plant for the whole experiment was 40 ranging between 23 and 59. The varieties "BT-3", "UKR 6/82", "UKR 1/82", "BT-4", "952-63" and "Waldspindel D" developed the highest number of tubers per plant. High variation between years was also observed for this trait which is known to be sensitive to plant density (Berenji and Kišgeci, 1988).

According to tuber size, "Violet Rennes", "B. Koviljača", "BT-4", "UKR 4/82", "Ozor" and "D-19" appeared to be the best performing cultivars out of the full range of 45-100 g measured in this experiment. Having in mind the great importance of the tuber size in establishing a fast-growing plantation of Jerusalem artichoke (Klaushofer and Schiesser, 1986), the larger tubers are advantageous not only as an influential yield component but also for as reliable planting material.

Table 4: Tuber size (g) of the Jerusalem artichoke varieties tested

Number	Variety	Year								Average	Rank
		1994	1995	1996	1997	1998	1999	2000	2001		
1	UKR 1/82	50	91	45	41	29	49	49	75	54	15
2	UKR 2/82	67	56	40	37	29	47	41	47	45	20
3	UKR 4/82	65	106	84	96	58	88	57	76	79	4
4	UKR 5/82	41	40	36	54	39	62	34	65	46	19
5	UKR 6/82	56	55	47	55	44	77	55	53	55	14
6	B. Koviljaèa	66	81	73	77	89	126	115	76	88	2
7	Violet Communes	58	54	40	64	41	61	55	85	57	11
8	Violet Rennes	87	93	92	114	75	97	107	132	100	1
9	Topianca	58	53	47	72	42	66	65	52	57	12
10	Fuseau 60	47	55	49	56	46	64	69	57	55	13
11	Ozor	64	83	65	56	47	78	50	75	65	5
12	D - 19	48	66	58	78	47	74	70	70	64	6
13	K-8	58	71	65	69	46	68	67	58	63	7
14	207-63	40	43	39	49	48	76	48	55	50	18
15	952-63	35	58	39	54	38	52	61	68	51	17
16	Waldspindel D	60	77	56	55	40	55	57	67	58	10
17	Waldspindel A	55	71	50	74	42	63	69	63	60	9
18	Bela	60	70	60	61	36	85	46	67	61	8
18	BT - 3	46	46	50	53	37	56	71	47	51	16
20	BT - 4	79	122	83	81	59	94	77	78	84	3
Average		57	69	56	65	47	72	63	68	62	

LSD at $P < 0.01$ probability level between varieties = 14; between years = 9; between indivudual cells = 23

According to Le Cochec (personal communication) the ideotype of Jerusalem artichoke includes few but large tubers per plant resulting in yield up to 1.5 kg/plant and 80 t/ha. In this respect the most promising varieties in this experiment were "BT-4", "Violet Rennes", "Ozor" and "UKR 4/82". It seems that tuber size has a stronger effect on tuber yield as compared with tuber number per plant.

The rank of varieties according to their performances was different from one year to another, indicating the existence of strong genotype-environment effects. This is supported by the results of ANOVA pointing to highly significant genotype, environment as well as genotype-environment effects for all of the traits studied (Table 5).

Table 5: Components od variation for tuber yield per plant, number of tubers per plant and tuber size based on the results achieved with 20 Jerusalem artichoke varieties grown during the period of 1994-2000

Source of variation	Degree of freedom	Statistical significance of the variation		
		Tuber yield per plant	Number of tubers per plant	Tuber size
Varieties	19	**	**	**
Years	7	**	**	**
Variety x Year	133	**	**	**

** = significant at $P<0.01$ probability level

The effect of environment *i.e.* years was of the same intensity as the genotype effect. Similar intensity of the genotype x environment effect was added to the variation of all of the traits studied. Such results indicate that for a successful production of Jerusalem artichoke it is necessary to select a variety with high genetic tuber yield potential, but it is equally important to provide optimal environmental conditions by careful selection of location and production practices applied.

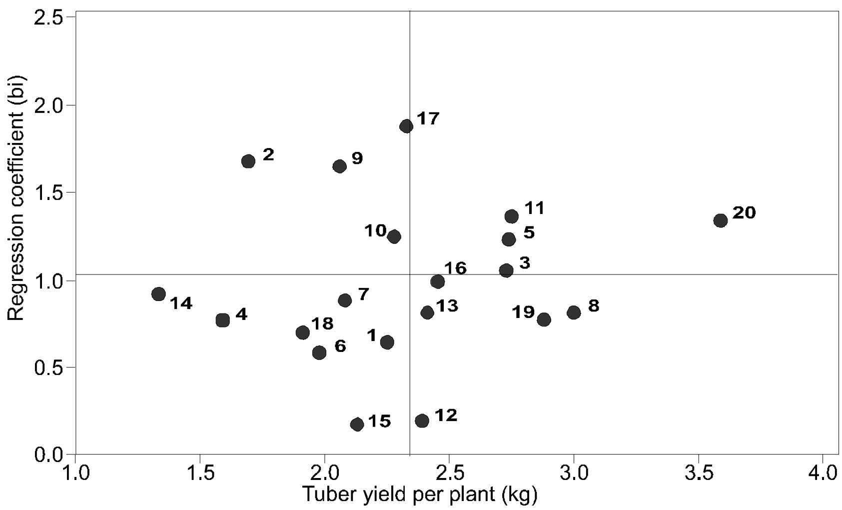

Figure 2: Tuber yield per plant and yield stability of 20 Jerusalem artichoke cultivars studied. Numbers correspond to the ordinal numerals in Table 1.

Having in mind the significance of genotype-environment interactions, stability parameters were calculated using the Eberhart and Russel (1966) model in order to determine those varieties showing the best yield performance combined with high yield stability (Figure 2). The most promising varieties showing high yield combined with high stability of yield over environments were "BT-4", "Violet Rennes" and "UKR 4/82". It was encouraging that the highest yielding varieties had a rather stable performance over environments. Good yield stability of a variety is an additional advantage to the well-documented broad adaptability of Jerusalem artichoke as a crop to different environments, including less fertile, marginal soils (Laberg and Sackston, 1987; Pekić *et al.*, 1983).

CONCLUSIONS

The results of this study showed a significant genetic and environmental variation for tuber yield per plant, number of tubers per plant and tuber size of Jerusalem artichoke. The significant variation between the varieties studied indicated the existence of considerable genetic variability for all of the traits measured. The highly significant year and variety x year effects pointed to the importance of the environmental factors *i.e.* cultural practices for the production of Jerusalem artichoke. The most promising varieties showing high yield combined with high stability of yield over environments were "BT-4", "Violet Rennes" and "UKR 4/82". It is desirable for the highest yielding varieties to have a stable performance over the different environments.

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VARIABILIDAD Y ESTABILIDAD DEL RENDIMIENTO DE TUBERCULOS DEL TOPINAMBO

RESUMEN

El objetivo de este trabajo es de hacer constar las variabilidades y estabilidades genetica y ecologica relativas al rendimiento de tuberculos por planta, el numero total de tuberculos por planta y la grandeza de tuberculos del topinambo a base de los resultados del experimento con 20 variedades del topinambo investigadas en el perido de 1994-2000. Todas las caracteristicas investigadas mostraron la variabilidad genetica y la variabilidad ecologica importantes. Las mejores variedades, que combinaban el alto rendimiento de tuberculos con la estabilidad del rendimiento, eran "BT-4", "Violet Rennes" y "UKR 4/82". Se considera como muy favorable lo que las variedades con el mas alto rendimiento tenian el rendimiento muy estabil en diversas condiciones del medio.

VARIABILITÉ ET STABILITÉ DU RENDEMENT DU TUBERCULE DE TOPINAMBUR

RÉSUMÉ

Le but de cet article était d'évaluer la variation génétique et écologique ainsi que la stabilité du rendement en tubercules par plante, le nombre de tubercules par plante et les dimensions du tubercule du topinambour selon les résultats d'une expérience effectuée sur 20 variétés de topinambours étudiées entre 1994 et 2000. Toutes les caractéristiques observées ont montré une variabilité génétique et écologique importante. Les meilleurs sortes, celles qui combinaient un grand rendement de tubercules et une stabilité de rendement ont été: "BT-4", "Violet Rennes" et "UKR 4/82". Les sortes les plus productives ont eu un rendement très stable dans différentes conditions du milieu, ce qui est considéré comme très avantageux.