Comparison of Yield Characters among the Hybrid Populations of Potato Having Different Wild Relatives in Their Ancestry*

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Abstract : In order to clarify the effect of wild relatives on the yield characters of their progenies, the tuber fresh yield, starch content and starch yield were compared among the populations of the first clonal generation derived from one male parent and 36 female parents which had different wild relatives in their ancestry.

The populations derived from the parents of CP group which had *S. chacoense* or *S. phureja* in the ancestry, tended to be higher in the starch content and starch yield compared with those from the parents of T group which had no wild relatives in the ancestry, and DW group which had the wild relatives other than *S. chacoense* or *S. phureja* in the ancestry (Table 1). The variations among the hybrids of each population in the starch content and starch yield also tended to be larger in the populations of CP group compared with those of T and DW groups. Although the starch yield showed significantly positive correlation with both tuber fresh yield and starch yield among all populations, the difference in the starch yield among the populations with its higher values was mainly due to the difference in the starch content (Fig. 1). Since the starch yield highly correlated with the tuber fresh yield among the hybrids of each population, the difference in the starch content between the populations was clearly exhibited by the difference in the regression lines between the starch yield and tuber fresh yield among the hybrids of each population (Fig. 2).

From these results, we concluded that using the parents of CP group for breeding crosses was more effective to get a new cultivar with high starch content and starch yield.

Key words : Breeding, First clonal generation, Potato, Starch content, Starch yield, Tuber fresh yield, Wild relatives.

異なる近縁野生種に由来するパレイショ交配分離集団間における収量形質の比較: 岩間和人・西部幸男*
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要 旨 : パレイショの近縁野生種(野生種)が後代の育種材料の収量形質に及ぼす影響を明らかにするために、異なる野生種に由来する36系統(品種)を母本とし、父本を共通とする交配から得た、第一次栄養繁殖世代の集団間における塊茎収量(生体重)、澱粉価および澱粉収量を比較した。

CP群(*S. chacoense*または*S. phureja*に由来する系統)を親とした集団は、T群(野生種に由来しない系統)およびDW群(*S. chacoense*または*S. phureja*以外の野生種に由来する系統)を親とした集団に比べ、澱粉価および澱粉収量の集団平均値が高く、また集団内の雑種個体間の変異が大きい傾向を示した(第1表)。各集団の澱粉収量は塊茎収量、澱粉価の両者と高い正の相関関係を示したが、澱粉収量の高い集団間では、澱粉収量の差異は主として澱粉価の差異に起因していた(第1図)。各集団の雑種個体間では、澱粉収量は塊茎収量と極めて密接な相関関係を示したが、集団間における澱粉価の差異は塊茎収量に対する澱粉収量の回帰直線の差異として現れた(第2図)。

以上のことから、CP群の系統を育種交配の親に用いることにより、塊茎の澱粉価および澱粉収量の高い品種を効率的に育成できるものと考えた。

キーワード : 育種, 塊茎収量, 近縁野生種, 第1次栄養繁殖世代, 澱粉価, 澱粉収量, パレイショ。

Since commercially cultivated potatoes have a relatively narrow gene pool^{1,5)}, the transmis-

sion of genes from wild relatives to breeding materials will be useful to increase the variation in potato breeding. Most of the parental lines used for the crosses in the Hokkaido National Agricultural Experiment Station during the last two decades have several wild relatives in their ancestry. The main purpose of the crosses with the wild relatives was to

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introduce disease and pest resistance to the cultivars. These crosses, however, may have affected on the yield characters of their progenies.

In the present experiment, the yield characters in the populations of the first clonal generation derived from 36 crosses were investigated in order to clarify the effect of wild relatives on the yielding ability of their progenies. These crosses had the same male parent and female parents which had different wild relatives in their ancestry. Some indications of the effect of the wild relatives on the yield characters of their progenies were obtained.

Materials and Methods

The analysis was made on the data of tuber fresh yield, starch content and starch yield in 36 hybrid populations of the first clonal generation grown in the Hokkaido National Agricultural Experiment station in 1983. The female parents except 3 cultivars derived from the backcrosses of the hybrids between *S. tuberosum* and wild relatives with *S. tuberosum*. The wild relatives used in the breeding of the female parents were listed in Table 1. Some parents could not be identified the name of wild relatives used in the crosses. In that case, "wild race" was written in Table 1. However, since the crosses with wild relatives in these lines were done during the time when *S. demissum* was mainly used as a parental material, "wild race" is probably *S. demissum*. Therefore, the female parents were divided into three groups by the wild relatives in their ancestry, namely; the T group, which consists of 3 cultivars having no wild relatives; the DW group, which has *S. deminnum*, *S. andigena*, *S. acaule* or "wild race" in the ancestry; the CP group, which has *S. chacoense* or *S. phureja* in the ancestry. The male parent of all populations was R392-50, which had *S. andigena* and "wild race" in the ancestry.

One tuber of each hybrid was planted on May 6 and 10 with 39 cm hill distance of 75 cm row width in the order of starch content (high to low) and the size of tuber (large to small) within a population. Fertilizers were applied in rows before planting at the rates of 100, 150, 100 kg/ha of N, P₂O₅, K₂O, respectively. Plants were killed on late August used by a herbicide in order to avoid the effect of the difference in harvesting date among the

materials on the yield characters. Harvesting was done during September 1 to 16. After recording the tuber fresh yield, the starch content was measured using the automatic specific gravity meter. The starch yield was calculated by multiplying the tuber fresh yield with the starch content.

Results

The mean values in the tuber fresh yield, starch content and starch yield among the hybrids of each population are shown in Table 1. The tuber fresh yield was the highest in the population with Benimaru parent, 1.8 times larger than that of the smallest population with R392-26 parent. The population with WB60015-7 parent had the highest starch content and starch yield, which were 1.6 times and 2.7 times larger than the smallest populations, respectively. Thus, there were large differences in three characters among the populations.

The populations derived from the parents of CP group tended to have higher values in the starch content and starch yield compared with the populations derived from the parents of T and DW groups. The mean values of CP group in the starch content and starch yield were 16% and 21% higher than those of T group, respectively, and the differences were statistically significant at 0.1% and 1% level, respectively. In addition, the variations among the hybrids of each population in these two characters tended to be larger in the populations of CP group than in those of T and DW groups. The mean values of standard deviation (SD) of CP group in the starch content and starch yield were 18% and 24% larger than those of T group, respectively.

Conceptually, the starch yield is the product of the tuber fresh yield and starch content, the starch yield showed significantly positive correlations with the both two characters among all populations (Fig. 1). Among the populations with the starch yield more than 161 g/hill (total mean value), however, the correlation of the starch yield with the tuber fresh yield was unclear ($r=0.047$). While, the positive correlation of the starch yield with the starch content was clear ($r=0.817^{**}$). These results indicate that the difference in the starch yield among the populations with its higher values was mainly due to the difference in the

Table 1. The wild relatives in the ancestry of the female parents of the hybrid populations, and the population mean, standard deviation (SD) and coefficient of variation (CV) in tuber fresh yield, starch content and starch yield.

Populations (female parents)	Wild rela- tives in ancestry	Number of hybrids	Fresh yield			Starch content			Starch yield		
			Mean (g/hill)	SD	CV (%)	Mean (%)	SD	CV (%)	Mean (g/hill)	SD	CV (%)
T group											
Danshakuimo	None	86	985	224	22.7	15.5	1.3	8.1	142	31.7	22.4
Benimaru	None	79	1153	323	28.0	16.2	1.3	8.0	175	48.2	27.5
May Queen	None	30	992	226	22.8	16.0	1.7	10.7	149	34.0	22.9
Group mean			1043	258	24.5	15.9	1.4	8.9	155	38.0	24.3
DW group											
Bihoro	D	88	1035	241	23.3	20.1	1.6	7.9	197	45.3	23.0
P. Dell	D	82	896	235	26.3	15.6	1.3	8.3	129	30.3	23.4
Rishiri	D	79	1027	293	28.5	16.7	1.4	8.7	161	46.5	28.9
63019-1	D	59	1133	270	23.8	15.6	1.4	8.8	166	42.3	25.5
HK-63	A, D	122	665	214	32.3	16.8	2.0	11.7	103	31.3	30.4
HK-66	A, D	78	1061	297	28.0	15.4	1.5	9.5	151	39.8	26.3
SH-525	A, D	60	927	195	21.1	15.5	1.3	8.3	134	28.7	21.4
SH-532	A, D	83	1008	250	24.8	15.4	1.3	8.2	145	35.2	24.4
Eniwa	W	111	877	204	23.3	17.0	1.3	7.7	140	32.8	23.4
Toyoshiro	W	82	1105	277	25.1	15.5	1.5	9.6	159	40.1	25.2
HK-50	W	85	969	202	20.8	14.4	1.2	8.6	129	24.7	19.2
HK-62	W	25	928	167	18.0	13.9	1.7	12.3	119	25.8	21.7
R392-26	A, W	15	654	156	23.8	14.9	1.3	8.7	90	19.1	21.1
R392-53	A, W	23	694	251	36.1	15.5	1.6	10.6	98	27.3	27.7
WB77018-16	Ac, W	19	915	209	22.8	15.7	1.1	7.2	134	25.4	19.0
Hokkaikogane	D, W	128	1050	255	24.3	15.1	1.4	9.5	147	32.3	22.0
Waseshiro	D, W	75	899	241	26.8	15.8	1.2	7.8	132	33.0	25.0
Group mean			932	233	25.2	15.8	1.4	9.4	137	32.9	24.0
CP group											
WB60015-7	C	55	1144	344	30.1	22.0	1.7	7.9	239	68.5	28.7
WB60094-3	C, P	70	965	214	22.2	21.8	2.1	9.7	202	50.1	24.9
WB65051-16	C, P	119	1029	177	17.2	18.9	1.5	7.9	184	32.7	17.7
Hatsufubuki	C, P, W	55	1136	242	21.3	16.6	1.5	9.2	176	37.0	21.0
Konafubuki	C, P, W	118	1046	278	26.6	18.3	1.7	9.5	181	49.5	27.4
WB61037-4	C, P, W	71	946	181	19.2	19.1	1.9	10.1	172	38.4	22.4
WB61037-94	C, P, W	81	1096	232	21.2	18.9	1.7	8.9	196	45.7	23.3
WB66201-10	C, P, W	120	977	223	22.9	20.6	1.6	7.6	191	43.9	23.0
71031-9	C, P, W	129	1109	313	28.2	18.6	2.1	11.5	195	56.6	29.1
74049-8	C, P, S, W	122	1077	279	25.9	18.1	1.4	7.9	184	49.5	26.9
HK-64	C, P, A, D, W	103	1035	271	26.2	16.9	1.8	10.7	164	45.1	27.5
HK-65	C, P, A, D, W	103	1107	248	22.4	16.2	1.6	9.9	169	44.2	26.1
HK-67	C, P, A, D, W	114	1103	270	24.4	17.8	1.5	8.6	186	50.0	26.6
SH-530	C, P, A, D, W	73	1147	287	25.0	17.2	1.8	10.6	186	51.3	27.6
HK-56	P, S, W	84	1099	258	23.5	17.0	1.6	9.6	175	39.3	22.4
SH-513	P, S, W	144	1121	285	25.4	17.6	1.5	8.8	185	47.9	25.9
Group mean			1071	256	24.0	18.5	1.7	9.3	187	46.9	25.1
Total mean			1003	245	24.6	17.0	1.5	9.1	161	39.5	24.5

1) D; *S. demissum*, W; Wild race (not identified, but may be *S. demissum*), A; *S. andigena*, Ac; *S. acaule*, C; *S. chacoense*, P; *S. phureja*, S; *S. stoloniferum*.

Fig. 1. The relations of starch yield with tuber fresh yield and starch content among the populations.

Note. $\triangle$: The populations of T group, $\square$: The populations of DW group, $\circ$: The populations of CP group.

starch content. The higher starch content of the populations of CP group resulted in the higher starch yield.

Among the hybrids of each population, the variation in the tuber fresh yield was apparently larger than the variation in the starch content. The mean value of the populations in the coefficient of variation (CV) of the tuber fresh yield was 25%, while that of the starch content was 9%. In addition, the correlation between the tuber fresh yield and starch content at each population was low. A single correlation coefficient between two characters was -0.3 to 0.1 at most of the populations. As a result, the difference in the starch yield among the hybrids of each population was mainly due to the difference in the tuber fresh yield. The single correlation coefficient between the tuber fresh yield and starch yield at each population was more than 0.9 at all populations except for one. As shown in Fig. 2, however, the populations of the different groups (T and CP) showed the different regression lines of the starch yield to the tuber fresh yield among the hybrids. Comparing the hybrids with the similar values in the tuber fresh yield, the hybrids with WB60015-7 parent of CP group tended to have higher starch yield than those with Benimaru parent of T group. This was due to the difference in the starch content among the hybrids of two populations.

Discussion

The present results clearly indicated that the populations derived from the parents of CP group tended to be higher in the starch

Fig. 2. The relations between tuber fresh yield and starch yield among the hybrids of two populations of the different groups (T and CP).

Note. $\circ$: The hybrids with Benimaru parent (T group), $\square$: The hybrids with WB 60015-7 parent (CP group).

content and starch yield compared with those from the parents of T and DW groups. Taguchi⁷⁾ reported the differences in the tuber fresh yield and starch content among 22 populations of the first clonal generation. The differences in the tuber fresh yield and starch content among the populations were 340 g/hill and 4.5%, respectively. While, in the present experiment, the differences in the tuber fresh yield and starch content among the populations were 500 g/hill and 8.1%, respectively. The difference in the starch content among the populations was apparently larger in the present materials compared with Taguchi's materials. Since the parents of the populations

used by Taguchi had no wild relatives in their ancestry, the increase of the difference in the starch content among the populations of the present materials compared to Taguchi's materials will be considered as an effect of the wild relatives used in the breeding of the parents.

Hawkes¹⁾ did not describe that *S. chacoense* and *S. phureja* had a high starch content in his explanation of the characteristics of the wild potato species. Nagata and Irikura⁴⁾, however, reported that *S. chacoense* showed a high starch content. Ruttencutter et al.⁶⁾ also found that the lines derived from the cross between *S. phureja* and *S. stenotomum* had a high starch content. Ross⁵⁾ described that wild relatives and their backcross hybrids were generally high in starch.

From these results, we concluded that the use of the parents which had *S. chacoense* or *S. phureja* in the ancestry increased the starch content and starch yield in the populations of the first clonal generation. Since the population with WB60015-7 parent, which had only *S. chacoense* in the ancestry, showed the highest starch content and starch yield among the populations, *S. chacoense* will be more probable as the gene source of high starch content and starch yield. Since the starch content has relatively high heritability and its relative order among the hybrids in the first clonal generation is consistent in the following generations^{5,6,7)}, we consider that using the parents of CP group in the breeding crosses is more effective to get a new cultivar with high starch content and starch yield.

In the present experiment, the effect of wild relatives on the tuber fresh yield was unclear. However, Hermundstad and Peloquin²⁾ have recently reported that the hybrids between haploid of *S. tuberosum* and several wild potato species produced very high tuber fresh yields, up to 3.1 kg/hill. Isoda et al.³⁾ also found the high yielding line of 135 t/ha from the hybrids

between *S. tuberosum* and *S. andigena*. Therefore, an increase in tuber fresh yield may also be expected when using the parents derived from the wild relatives in the breeding crosses. We need more frequent use of the wild relatives for the breeding crosses not only to introduce the disease and pest resistant genes but also to produce gene combinations that consequently bring higher productivity.

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