STUDIES ON THE METHODS OF BREEDING IN POTATO PLANTS

2. EFFECT OF YEAR AND LOCATION ON THE MANIFESTATION OF THE CHARACTERISTICS OF SOME VARIETIES

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馬鈴薯の育種法に関する研究

第2報　数品種の形質発現に対する年次と地域の影響

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The final assessment of adaptability will depend upon how well the variety is accepted by farmers in various locations over a period of years. In this report, the response of the characteristics or varieties to locational or seasonal variation is analyzed. It is not necessary to take many years to evaluate varietal difference of adaptability in characteristics such as date of maturity or tuber weight, but necessary to take many locations except stem length and tuber yield. It is found that the tuber number which is controlled mainly by predictable factors has a great effect on starch yield.

I INTRODUCTION

The phenotypic variations of characteristics concerned with the starch yield in potato plants are introduced by given environmental factors. Some vary mostly with local factors and the others with seasonal factors. Furthermore, there will exist differences in adaptability for location and/or year among varieties. Plant breeders want to improve new varieties having a wide local adaptability in consecutive years.

STEVENSON *et al.*[7] reported that there are inherent differences among varieties in their ability to produce high dry matter, but often differences caused by environment are greater than the varietal differences. Judging from the seed list, AKELEY[1] also noted that popularity is different among varieties, and Katahdin and Kennebec have wide adaptation. Furthermore, PLAISTED anb PETERSON[6] reported the technique for evaluating the ability of selection to yield consistently in different locations or seasons. This method was one of the methods developed by HORNER and FREY[5] and should be a valuable technique for the breeder to use in making his decision concerning the release of a selection as a named variety. But statistical analyses were not done on other characteristics of potato plants. To know the differences in genotype by environment interaction for characteristics is also an important step for the breeder and farmer.

For this purpose the authors analyzed the macro environmental variation of characteristics in potato plants.

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II MATERIALS AND METHODS

For the purpose of estimating adabtability,

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data for five years at six locations involving four varieties of potato plants were available. The locations were widely scattered in Hokkaido, the northenmost part of Japan. The varieties used were Norin No. 1, Benimaru, Eniwa and Hokkaiaka. Data for the five years from 1962 to 1966 were used. The replications varied from two to four at the various sites, but the mean was used for the statistical calculation. The characteristics in question are respectively:

1. *stem length* at the end of anthesis ;
2. *date of maturity* (number of days from the lst of August) ;
3. *damage index of late blight* (*Phytopthora infestans*) ;
4. *tuber number* per 0.1 hectare ;
5. *tuber weight* (average weight of one tuber) ;
6. *tuber yield* per 0.1 hectare in kilogram ;
7. Reiman' *starch value* (estimated starch content + 1 in per cent) ; and
8. *starch yield per* 0.1 hectare in kilogram.

III RESULTS AND DISCUSSION

Analysis of variance of all characteristics through five years and six locations are given in Table 1. The differences among varieties, locations and years were highly significant at one per cent level, respectively. Relatively large mean squares for varieties were observed in the damage index of late blight and in starch value, and those two characteristics are known as having high repeatability [3].

ALLARD *et al.*[2] divided the variation of environment into two sorts, predictable and unpredictable. The effect of location (*i. e.*, predictable variation) on the variation of stem length and tuber number was large, starch yield tuber yield followed them. Namely, those characteris tics showed great differences among locations. Meanwhile, the variance among years, unpredictable variation, was large in date of maturity, tuber weight and yield. Therefore, it may be suggested that the seasonal variation of yield is more affected by tuber weight than tuber num ber. Because of location × year interactions in all characteristics were significant, the data in each location varied depending on the year. The differences among varieties concerning the date of maturity, tuber weight and starch yield were distinct, but the highly significant interaction of variety by year in yield suggested that the varieties responded differently depending on the year. Thus, the agronomic characteristics were much influenced by the different environments and the inflence of environment on characteristics and varieties was different according to the location and the year.

The effect of variety and year was significant for those five years ; but we need several more years to evaluate characteristics such as tuber yield having a large variety × year interaction. On the contrary fewer years are needed to study characteristics as date of maturity, tuber weight such and starch yield. The interactions of variety by location were significant for all characteristics except stem length and tuber yield. It is necessay

Table 1. Analysis of variance

Sources	D. F.	Stem length	Damage index of late blight	Date of maturity	Tuber number	Tuber weight	Tuber yield	Starch value	Starch yield
Total	119								
Varieties	3	689**	23.96**	654**	23,808**	874.3**	10,326**	93.87**	137,010**
Locations	5	2,686**	1.76**	672**	41,930**	753.3**	51,123**	7.27**	194,381**
Years	4	664**	10.14**	1,371**	15,351**	4,678.2**	48,026**	13.25**	102,965**
V × L	15	34	.16**	71**	2,469**	267.8**	3,890	1.45**	5,912*
V × Y	12	49*	.60**	14	2,799**	102.5	15,756**	1.37**	5,330
L × Y	20	452**	4.28**	173**	7,419**	445.2**	5,634**	3.34**	9,680**
V × L × Y	60	23	.02	12	933	68.0	2,117	.41	3,038

*, ** The corresponding mean squares were significant at 5 and 1 % levels, respectively.

to take various locations to find differences among varieties in the characteristic which is relatively variable in varietal order by locations (*e. g.*, damage index of late blight, tuber number and starch value and date of maturity, *etc.*). There existed significant variety × location interactions for tuber number and tuber weight but no significant interactions in tuber yield. This fact suggests that there is a stable varietal order of yield as a result of mutual compensa-

Table 2. Effect of year and location on changes of characteristics

Characteristics	Varieties	Effect (%) †			Mean
		Year	Location	Y × L (Err.)	
Stem length	Norin No. 1	0	34.1 *	65.9	71 cm
	Benimaru	0	44.7 **	55.3	76
	Eniwa	7.2	49.7 **	43.1	77
	Hokkaiaka	11.1	33.7 **	55.2	82
Damage index of late blight	Norin No. 1	6.6	0	93.4	2.0
	Benimaru	74.6 **	1.3	24.1	2.2
	Eniwa	6.9	0	93.1	.8
	Hokkaiaka	20.0	9.7	70.3	.3
Date of maturity	Norin No. 1	31.6 **	25.9 **	42.5	48 days
	Benimaru	41.4 **	17.8 *	40.8	48
	Eniwa	33.1 **	21.5 *	45.4	49
	Hokkaiaka	28.7 **	28.6 **	42.7	58
Tuber number	Norin No. 1	9.4	43.3 *	47.3	303 × 100
	Benimaru	3.8	14.8	81.4	360
	Eniwa	0	33.0 *	67.0	304
	Hokkaiaka	21.0	45.6 **	33.4	340
Tuber weight	Norin No. 1	53.3 **	11.5 *	35.2	102 g
	Benimaru	43.1 **	9.7	47.2	90
	Eniwa	31.2 *	0	68.8	101
	Hokkaiaka	38.5 **	25.1 **	36.4	96
Tuber yield	Norin No. 1	14.7 **	55.5 **	29.8	3,000 kg
	Benimaru	14.6 *	41.2 **	44.2	3,188
	Eniwa	62.0 **	10.2 *	27.8	3,452
	Hokkaika	1.8	39.5 **	58.7	3,201
Starch value	Norin No. 1	32.5 **	21.1 *	46.4	16.1 %
	Benimaru	35.3 **	.9	63.8	15.6
	Eniwa	21.1 *	12.6	66.3	18.1
	Hokkaiaka	2.3	33.2 *	64.5	19.4
Starch yield	Norin No. 1	25.0 **	57.5 **	17.5	460 kg
	Benimaru	33.4 **	39.8 **	26.8	473
	Eniwa	28.5	56.7 **	14.8	521
	Hokkaiaka	2.5	51.4 *	46.1	609

*, ** show that variance of year or location is significant at 5 and 1 % levels, respectively.

† Effect of year $= \frac{\text{Year SS} - (\text{Year DF})(\text{Error MS})}{\text{Total SS}} \times 100$

Table 3. Effect of year and varieties on changes of characters at different locations

Characteristics	Locations	Effect (%)			Mean
		Year	Variety	Y×V (Err.)	
Stem length	Kamikawa	40.9 *	18.0	41.1	78 cm
	Kitami	82.9 **	2.9	14.2	89
	Tokachi	76.1 **	18.2 **	5.7	89
	Shimamatsu	57.1 **	8.2	34.7	79
	Konsen	44.1 **	33.8 **	22.1	69
	Tenpoku	55.2 **	20.8	24.0	58
Damage index of late blight	Kamikawa	25.5 *	43.6 **	30.9	1.5
	Kitami	54.6 **	6.8 *	38.6	1.5
	Tokachi	70.6 **	16.4 **	13.0	1.7
	Shimamatsu	12.1	54.0 **	33.9	1.3
	Konsen	28.6 *	35.3 **	36.1	1.0
	Tenpoku	30.1 *	16.8	53.1	1.0
Date of maturity	Kamikawa	75.3 **	14.5 **	10.2	55 days
	Kitami	93.9 **	1.8 *	4.3	51
	Tokachi	84.0 **	4.2	11.8	42
	Shimamatsu	47.3 **	10.3	42.4	51
	Konsen	62.1 **	26.0	11.9	58
	Tenpoku	13.6 **	73.3 **	13.1	47
Tuber number	Kamikawa	61.6 **	15.8 *	22.6	367×100
	Kitami	59.9 **	—	40.1	372
	Tokachi	41.9 **	28.5 **	29.6	364
	Shimamatsu	40.4 **	32.5 **	27.1	302
	Konsen	31.1 *	15.3	53.6	275
	Tenpoku	29.3 *	14.6	56.1	280
Tuber weight	Kamikawa	80.8 **	3.0	16.2	104 g
	Kitami	73.9 **	—	26.1	102
	Tokachi	65.6 **	6.9	27.5	87
	Shimamatsu	43.2 **	31.5 **	25.3	99
	Konsen	17.6	32.8 *	49.6	95
	Tenpoku	68.7 **	23.0 **	8.3	95
Tuber yield	Kamikawa	67.2 **	11.5 *	21.3	3,679 kg
	Kitami	36.7 *	—	63.3	3,923
	Tokachi	30.5	—	69.5	3,291
	Shimamatsu	56.5 **	14.0 *	29.5	2,886
	Konsen	27.3	—	72.7	2,745
	Tenpoku	16.8	1.2	82.0	2,738
Starch value	Kamikawa	—	84.7 **	15.3	18.2 %
	Kitami	21.8 **	47.6 **	30.6	17.3
	Tokachi	40.0 **	44.0 **	16.0	17.1
	Shimamatsu	57.4 **	32.5 **	10.1	17.2
	Konsen	14.9	70.8 **	14.3	17.5
	Tenpoku	4.6	79.2 **	16.2	16.4
Starch yield	Kamikawa	26.4 **	59.5 **	14.1	637 kg
	Kitami	47.7 **	14.7	37.6	627
	Tokachi	56.6 **	19.3 **	24.1	528
	Shimamatsu	58.5 **	2.4	39.1	465
	Konsen	47.4 **	21.5	31.1	431
	Tenpoku	13.3	56.5 **	30.2	407

*, ** From the analysis of variance, those were significant at 5 and 1 % levels of probability, respectively.

tion between tuber number and tuber weight in every location.

Moreover diffence in variety was compared considering the effect of year and location according to TAGUCHI's method [8] as shown in Table 2. In general, the effect of year on the variation of characteristics in date of maturity, tuber weight and starch yield was great. Also, the effect of locations on the variation of characteristics in stem length, tuber number and tuber yield was great. Effect of error (year × location interaction) for starch yield was generally smallest in those treated characteristics. From this fact, starch yield is a stable characteristics and is easy to compare variety differences. Damage index of late blight in Benimaru, the most susceptible variety in this test, and the yield of Eniwa were influenced greatly depending on the year. On the contrary, starch yield of Hokkaiaka accepted greatly the effect of local and error. Thus responses for environments were different according to varieties or characteristics.

Similarly the effects of variation of year and variety under different locations are given in Table 3. Large yields were produced in Kamikawa, Kitami and Tokachi, and smaller yields in other locations. In the above mentioned locations general features of climatic condition may be more suitable for the growing of potato plants than in other low productive locations. Stem length was influenced mostly by year and its varietal differences were found at Tokachi and Konsen, meanwhile there was no difference at other locations. In the case of damage index of late blight, the effect of variation of variety was large at Kamikawa, Shimamatsu and Konsen, on the other hand the effect of variation of year was larger at Kitami, Tokachi and Tenpoku than at other locations. Concerning date of maturity, the effect of variation of year was larger than that of variety at Tenpoku, but at Shimamatsu the error (variety × year interaction) was larger. In the case of tuber number, varietal difference was significant at Kamikawa, Tokachi and Shimamatsu. Tuber weight varied comparatively by year at the highly productive area, namely, Kamikawa, Kitami and Tokachi ; while varietal difference could be found in other locations. In general, the large effect of difference of variety and the small effect of error variance were found in the starch value.

The effects of variation of the variety and the year were generally great in starch yield. At Kamikawa and Tenpoku the effects of vatiation of the variety were great and the effects of variation of year were small, as seen similarly in starch value. Starch yield would be decided as a product of tuber number × tuber weight × starch content and it is mainly controlled by tuber number or tuber weight because of little variation of starch value. Particularly tuber weight varies with an unpredictable factor such as climatic condition of a given year.

Similar results were obtained from path-co-

Table 4. Path-coefficient analysis of important characteristics concerned with starch yield under 30 different environments

	Norin No. 1			Benimaru			Eniwa			Hokkaiaka		
	Tuber number X_1	Tuber weight X_2	Starch value X_3	X_1	X_2	X_3	X_1	X_2	X_3	X_1	X_2	X_3
Corr. coef.	.466**	.395*	.575**	.346	.764**	.533**	.561**	.521**	.484**	.509**	.299	.316
Direct effect	.961	.737	.361	.586	.782	.334	.823	.708	.274	.974	.717	.391
Indirect effect via X_1		−.547	−.203		−.141	−.090		−.286	−.047		−.505	−.234
Indirect effect via X_2	−.419		.417	−.188		.289	−.246		.257	−.371		.159
Indirect effect via X_3	−.076	.204		−.051	.123		−.016	.099		−.094	.089	
Residual factors		.232			.205			.192			.408	
Multiple corr.		.973**			.989**			.981**			.913**	

*, ** Significant at 5 and 1 % levels of probability, respectiyely.

efficient analysis [4] of factors influencing starch yield in Table 4 [a]. In general, the direct effect upon starch yield was large in tuber number and small in starch value. Tuber number is a relatively important characteristics except in Benimaru, and that varied widely with locations. Because tuber numder has a great effect on starch yield, the manipulation of predictable factors of environment is the most effective method for raising starch yield at given site.

IV SUMMARY

Based on the data of variety tests for productibility in Hokkaido, the degree of phenotypic variation of several characteristics concerned with starch yield among varieties at locations and years was analyzed.

Stem length, tuber number and starch yield varied mostly with location, while tuber weight and date of maturity varied with the year. Stable varietal differences in characteristics such as starch value and damage index of late blight were found.

Furthermore there were differences among varieties depending on the location and year. And also the effects of variation of year and variety varied between locations.

Generally, it is not necessary to take many years to evaluate varietal differences in characterstics such as date of maturity. On the other hand it needs many locations to assess varietal difference in characteristics except stem length and tuber yield.

Tuber number is a relatively important characteristics which controls starch yield. Also, starch yield is mainly decided by predictable factors. At the locations producing high yields, tuber number was controlled depending on year and also the effect of tuber weight between varieties was small.

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a) Some part of this calculation was done through the kindness of the Computing Center for Research in Agriculture, Forestry and Fishery.

VI 摘 要

馬鈴薯の 2, 3 の実用的形質につき異なる環境での表現性の違いを北海道内 6 場所, 5 年間, 4 品種の資料から検討し, 次の結果を得た。

環境よりも品種の違いの効果が大きかったのは疫病被害程度と澱粉価であり, 品種別に比較的安定していた。一方地域による影響の受けやすい形質は茎長, 上いも数, ついで上いも重, 澱粉収量であった。また年次による影響は枯凋期, 上いも平均一個重において比較的大きく, 形質により地域あるいは年次の影響のうけ方に差異がみられた。

適応性の品種間差を知るには, 上いも重, 茎長およびある日時の疫病被害程度は相対的に長い年数での検討が必要で枯凋期, 上いも平均一個重, 澱粉収量および澱粉価では少なくてよい。一方, 茎長と上いも重以外の形質では比較的多くの場所での検討が必要である。

品種別にみると, 年次の影響の現われやすいのは「紅丸」の疫病被害程度,「エニワ」の上いも重などであり, 地域の影響は「ホッカイアカ」に大きく現われていた。

これを地域別にみると, 多収な地域では一般に上いも数に対する年次変動の影響が大きく, 一個重に対する品種の差による効果が少なかった。上

川では上いも数と一個重したがって上いも重の年次変動が大きいが，澱粉価は品種別に安定していた。天北では澱粉価が安定し，澱粉収量の年次変動が少ない。逆に，十勝，島松では澱粉価が年次の影響をうけやすい。上川，島松での上いも重は年次変動が大きいが，品種の年次による変化がほかの地域より少なかった。

一般に上いも数の澱粉収量に対する効果が大きいので，上いも数をますように環境の改善を図るのが効果的である。