Influence of Location on the Chemical Composition of Soybean Seeds

II. Potassium, phosphorus, magnesium, and calcium contents*

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There is little information on the effect of geographical location and climate on mineral constituents of the seeds of soybean varieties. Viljoen⁸⁾ have reported that the ash, phosphorus, and fiber values remain very constant, whereas the oil and protein contents of the different varieties show relatively great variability. Smirnova and Lavrova⁵⁾ have concluded that the amount of ash in several soybean varieties grown at different stations differed but little from one another. However, Cartter and Hopper²⁾ have reported that the ash, potassium, and phosphorus contents of the seeds appear to be influenced by a number of factors and more significantly soil type and fertility rather than variety or variations in climate, whereas the calcium content was significantly influenced by the temperature levels than variety²⁾. On the magnesium content, there is no literature on the influence of growing behavior and condition. On the other hand, in Japan, no attempt has been made to investigate the influence of cultural conditions on mineral constituents.

In the previous paper⁶⁾, we have reported the influence of seed characters and climatic environments on the chemical composition, *i.e.* protein, oil, carbohydrate, and ash contents of soybean seeds. In this paper, we further investigated the influenced factors on some mineral constituents, namely, potassium, phosphorus, magnesium, and calcium in soybean seeds.

MATERIALS AND METHODS

Thirty varieties of soybean were cultivated at 3 locations of Japan, namely, Ishioka, Shiojiri, and Kumamoto in 1963. The data on the cultural conditions, seed characters, and chemical com-

position, *i.e.* protein, oil, carbohydrate, and ash, have been presented in the previous paper⁶⁾.

The mineral constituents were determined by the following method; ash: burning for 4 hours at 600°C in a muffle furnace; potassium: flame photometric method used with Lange-5 flame photometer; phosphorus: the Nakamura modification of the Allen method⁴⁾; calcium: the Kubo-Tsutsumi semi-micro modification of the Ingols and Murray method³⁾; magnesium: atomic absorption spectroscopy method using Perkin-Elmer 303 atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The estimated values of potassium, phosphorus, magnesium, and calcium are given in table 1 as per cent on dry matter basis and in table 2 as per cent in ash. The statistical results are presented in table 3. Correlation coefficients between mineral constituents and estimated seed characters or climatic environments are shown in table 4 and 5.

1. Potassium.

a. Variation in potassium content: Among the 30 varieties, the potassium content on dry matter basis varied from 1.56 to 2.00% (mean: 1.762%) at Ishioka, from 1.47 to 1.87% (mean: 1.686%) at Shiojiri, and from 1.28 to 2.05% (mean: 1.691%) at Kumamoto (table 3). In the previous paper⁶⁾, the ash content showed the location variance, *i.e.* high content at Kumamoto. On the other hand, the location variance was not observed in the potassium content. However, the coefficient of variation of Kumamoto was higher (12.60%) than that of Ishioka (5.68%) or Shiojiri (6.23%) (table 3). Cartter and Hopper²⁾ have observed that the potassium content of the 10 common varieties at

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Table 1. Mineral composition of soybean seeds grown at three locations.

Constituent* Location Variety	K			P			Mg			Ca		
	Ishioka	Shiojiri	Kumamoto	Ishioka	Shiojiri	Kumamoto	Ishioka	Shiojiri	Kumamoto	Ishioka	Shiojiri	Kumamoto
Kanagawa-wase	1.85	1.87	1.94	0.714	0.705	0.799	0.308	0.224	0.297	0.296	0.263	0.401
Kairyoshirome	1.59	1.54	1.66	0.575	0.500	0.669	0.237	0.233	0.234	0.254	0.194	0.205
Matsuura	1.72	1.47	1.70	0.639	0.530	0.720	0.265	0.237	0.294	0.301	0.177	0.320
Fujimusume	1.65	1.62	1.86	0.580	0.486	0.689	0.250	0.229	0.267	0.388	0.198	0.391
Ichigo-wase	1.59	1.73	2.05	0.715	0.692	0.846	0.304	0.296	0.320	0.288	0.254	0.411
Bonminori	1.83	1.79	1.96	0.512	0.558	0.669	0.233	0.243	0.323	0.268	0.155	0.276
Harosoy	1.83	1.71	1.91	0.594	0.593	0.742	0.267	0.257	0.295	0.298	0.230	0.310
Shirasaya No. 1	1.78	1.80	1.84	0.681	0.662	0.705	0.291	0.273	0.281	0.272	0.178	0.288
Yamabe	1.65	1.80	1.68	0.517	0.507	0.679	0.223	0.229	0.254	0.227	0.126	0.300
Aisa	1.80	1.73	1.87	0.608	0.527	0.722	0.212	0.213	0.248	0.225	0.139	0.270
Sayohime	1.80	1.71	1.78	0.647	0.482	0.667	0.265	0.234	0.305	0.317	0.196	0.304
Kogandaizu	1.74	1.57	1.77	0.619	0.536	0.744	0.232	0.223	0.253	0.301	0.187	0.337
Shirobana-sai No. 1	1.90	1.76	1.62	0.627	0.610	0.731	0.242	0.242	0.275	0.268	0.179	0.332
Katazaya	2.00	1.80	1.61	0.548	0.579	0.696	0.234	0.236	0.260	0.361	0.209	0.395
Kimusume-Ibaraki No. 1	1.82	1.53	1.54	0.565	0.533	0.746	0.249	0.238	0.276	0.286	0.186	0.331
Norin No. 1	1.56	1.70	1.28	0.545	0.538	0.706	0.223	0.250	0.261	0.337	0.230	0.422
Norin No. 2	1.72	1.73	1.30	0.590	0.578	0.756	0.221	0.226	0.290	0.290	0.140	0.343
Ibarakimame No. 7	1.80	1.56	1.56	0.603	0.594	0.729	0.218	0.249	0.299	0.287	0.192	0.338
Ou No. 13	1.79	1.63	1.42	0.601	0.544	0.804	0.235	0.249	0.328	0.299	0.185	0.504
Hatsukari	1.77	1.55	1.70	0.561	0.546	0.797	0.226	0.235	0.250	0.271	0.169	0.407
Dekisugi No. 1	1.78	1.70	1.37	0.583	0.544	0.833	0.248	0.245	0.293	0.347	0.191	0.481
Ani	1.79	1.78	1.31	0.566	0.487	0.825	0.222	0.224	0.244	0.322	0.206	0.368
Shinanomejiro	1.82	1.70	1.80	0.579	0.466	0.801	0.232	0.240	0.270	0.289	0.192	0.446
Tachisuzunari	1.87	1.64	1.42	0.551	0.502	0.795	0.224	0.216	0.274	0.292	0.155	0.524
Akazaya	1.82	1.56	1.70	0.636	0.488	0.804	0.238	0.236	0.282	0.279	0.190	0.386
Shiromeyutaka	1.85	1.72	1.97	0.606	0.532	0.819	0.229	0.222	0.255	0.241	0.135	0.265
Nemashirazu	1.64	1.77	1.88	0.562	0.493	0.799	0.254	0.258	0.270	0.324	0.206	0.419
Hakuo	1.63	1.72	1.77	0.600	0.535	0.812	0.248	0.263	0.281	0.286	0.201	0.346
Kojirazu	1.70	1.55	1.77	0.647	0.578	0.809	0.250	0.242	0.280	0.244	0.177	0.358
Oguradaizu	1.77	1.83	1.70	0.571	0.598	0.812	0.248	0.236	0.270	0.263	0.175	0.350

* % on dry matter basis.

Table 2. Mineral composition of soybean seeds grown at three locations.

Constituent* Location	K			P			Mg			Ca		
Variety	Ishioka	Shiojiri	Kumamoto	Ishioka	Shiojiri	Kumamoto	Ishioka	Shiojiri	Kumamoto	Ishioka	Shiojiri	Kumamoto
Kanagawa-wase	30.0	30.8	28.9	12.9	11.6	11.9	5.00	3.69	4.43	4.81	4.33	5.98
Kairyoshirome	29.6	30.4	30.2	10.7	9.9	12.2	4.41	4.60	4.25	4.73	3.83	3.73
Matsuura	28.5	28.8	27.7	10.6	10.4	11.7	4.39	4.64	4.80	4.99	3.46	5.22
Fujimusume	28.7	32.0	29.3	10.1	9.6	10.9	4.36	4.52	4.20	6.76	3.91	6.16
Ichigo-wase	25.6	29.2	31.9	11.5	11.7	12.2	4.90	5.00	4.60	4.64	4.29	5.91
Bonminori	33.4	33.9	31.9	9.3	10.6	10.9	4.25	4.60	5.25	4.89	2.94	4.49
Harosoy	31.6	31.5	29.2	10.2	10.9	11.4	4.60	4.74	4.52	5.14	4.24	4.75
Shirasaya No. 1	30.7	31.7	29.6	11.8	11.7	11.4	5.03	4.81	4.52	4.70	3.14	4.64
Yamabe	33.5	35.8	29.2	10.5	10.1	11.8	4.53	4.55	4.41	4.61	2.50	5.21
Aisa	34.7	34.2	31.8	11.7	10.4	12.3	4.08	4.21	4.22	4.34	2.75	4.59
Sayohime	30.9	31.6	29.1	11.1	8.9	10.9	4.55	4.33	4.99	5.44	3.62	4.98
Kogamedaizu	29.8	31.4	27.7	10.6	10.7	11.7	3.97	4.46	3.97	5.15	3.74	5.28
Shirobana-sai No. 1	32.3	32.0	26.0	10.7	11.1	11.8	4.12	4.40	4.42	4.56	3.25	5.34
Katazaya	34.4	33.2	26.2	9.4	10.7	11.3	4.03	4.35	4.23	6.21	3.86	6.43
Kimusume-Ibaraki No. 1	33.5	30.9	26.1	10.4	10.8	12.6	4.59	4.81	4.67	5.27	3.76	5.60
Norin No. 1	29.0	33.1	22.6	10.1	10.5	12.5	4.14	4.87	4.61	6.26	4.48	7.46
Norin No. 2	31.0	32.8	21.9	10.6	10.9	12.7	3.99	4.28	4.89	5.23	2.65	5.78
Ibarakimame No. 7	31.6	30.2	24.7	10.6	11.5	11.6	3.82	4.83	4.74	5.04	3.72	5.36
Ou No. 13	32.7	31.7	21.6	11.0	10.6	12.3	4.30	4.83	5.00	5.47	3.59	7.68
Hatsukari	32.2	31.6	27.6	10.2	11.1	12.9	4.12	4.79	4.06	4.94	3.44	6.61
Dekisugi No. 1	32.2	35.1	22.0	10.5	11.2	13.4	4.48	5.05	4.70	6.27	3.94	7.72
Ani	33.0	35.3	21.7	10.4	9.7	13.7	4.09	4.44	4.05	5.93	4.09	6.10
Shinanomejiro	33.5	33.3	28.9	10.6	9.1	12.9	4.26	4.70	4.34	5.31	3.76	7.17
Tachisuzunari	33.5	33.5	23.5	9.9	10.2	13.1	4.01	4.41	4.53	5.23	3.16	8.66
Akazaya	32.2	32.7	27.5	11.2	10.2	13.0	4.20	4.95	4.56	4.93	3.98	6.25
Shiromeyutaka	33.2	35.9	31.6	10.9	11.1	13.1	4.11	4.63	4.09	4.33	2.82	4.25
Nemashirazu	29.4	33.9	28.2	10.1	9.4	12.0	4.55	4.94	4.05	5.81	3.95	6.28
Hakuo	30.2	33.6	28.1	11.1	10.4	12.9	4.59	5.14	4.47	5.30	3.93	5.50
Kojirazu	31.1	30.2	28.6	11.8	11.3	13.1	4.57	4.72	4.52	4.46	3.45	5.78
Oguradaizu	31.4	33.6	27.0	10.1	11.0	12.9	4.40	4.34	4.29	4.66	3.22	5.56

* % in ash.

Table 3. Mineral composition of thirty varieties of soybean seeds grown at three locations.

Constituent	Location	Extremes	Mean	L.S.D.*	Standard deviation	Coefficient of variation %
Per cent on dry matter basis						
K	Ishioka	1.56 — 2.00	1.762		0.100	5.68
	Shiojiri	1.47 — 1.87	1.686	0.09089	0.105	6.23
	Kumamoto	1.28 — 2.05	1.691		0.213	12.60
	3 whole locations	1.28 — 2.05	1.713		0.151	8.81
P	Ishioka	0.512 — 0.715	0.5981		0.0498	8.33
	Shiojiri	0.466 — 0.705	0.5508	0.03391	0.0601	10.91
	Kumamoto	0.667 — 0.846	0.7575		0.0562	7.42
	3 whole locations	0.466 — 0.846	0.6354		0.1044	16.43
Mg	Ishioka	0.212 — 0.308	0.2443		0.0241	9.86
	Shiojiri	0.213 — 0.296	0.2399	0.01343	0.0173	7.21
	Kumamoto	0.234 — 0.328	0.2776		0.0237	8.54
	3 whole locations	0.212 — 0.328	0.2539		0.0275	10.83
Ca	Ishioka	0.225 — 0.388	0.2907		0.0371	12.76
	Shiojiri	0.126 — 0.263	0.1872	0.03106	0.0319	17.04
	Kumamoto	0.205 — 0.524	0.3609		0.0728	20.17
	3 whole locations	0.126 — 0.524	0.2796		0.0875	31.29
Per cent in ash						
K	Ishioka	25.6 — 34.7	31.45		2.04	6.49
	Shiojiri	28.8 — 35.9	32.46	1.464	1.85	5.70
	Kumamoto	21.6 — 31.9	27.34		3.14	11.49
	3 whole locations	21.6 — 35.9	30.42		3.27	10.75
P	Ishioka	9.3 — 12.9	10.69		0.75	7.02
	Shiojiri	8.9 — 11.7	10.58	0.4639	0.74	6.99
	Kumamoto	10.9 — 13.7	12.24		0.78	6.37
	3 whole locations	8.9 — 13.7	11.17		1.07	9.58
Mg	Ishioka	3.82 — 5.03	4.348		0.306	7.04
	Shiojiri	3.69 — 5.14	4.621	0.1885	0.302	6.54
	Kumamoto	3.97 — 5.25	4.479		0.315	7.03
	3 whole locations	3.69 — 5.25	4.483		0.324	7.23
Ca	Ishioka	4.33 — 6.76	5.180		0.619	11.95
	Shiojiri	2.50 — 4.48	3.593	0.4879	0.520	14.47
	Kumamoto	3.73 — 8.66	5.816		1.118	19.22
	3 whole locations	2.50 — 8.66	4.863		1.225	25.19

* L.S.D. indicates the least difference required for significance at the 5% level.

5 locations during 5 seasons (1936-40) was from 1.29 to 2.17% with a mean of 1.67% on dry matter basis. They noted that seeds of the 10 varieties differed significantly in the potassium content, and the potassium content of the varieties did not remain as constant statistically through the seasons as did either phosphorus content or ash content. On our experiment, however, the coefficient of variation of potassium (except Kumamoto) was lower than that of any other mineral constituent.

The potassium content in ash was varied from 25.6 to 34.7% (mean: 31.45%) at Ishioka, from 28.8 to 35.9% (mean: 32.46%) at Shiojiri, and from 21.6 to 31.9% (mean: 27.34%) at Kumamoto (table 3). From the results, the potassium content at Kumamoto shows low mean value. Regardless high ash content at Kumamoto, the potassium content on dry matter basis did not showed higher as compared with other two locations (table 3). It is presumed that the reason is the low potassium content in ash content at Kumamoto. The

coefficient of variation of Kumamoto is higher (11.49%) than that of Ishioka (6.49%) or Shiojiri (5.70%), as shown in table 3.

b. Correlation with cultural conditions and chemical constituents: The potassium content on dry matter basis showed no correlation with the estimated characters, climatic environments, and chemical constituents at each location. At Kumamoto, however, only a negative correlation was observed with amount of totalized precipitation from flowering to maturity and from seeding to maturity, and also a negative correlation was observed with carbohydrate and calcium contents. The potassium content showed a positive correlation with ash (Shiojiri and Kumamoto) and phosphorus (Shiojiri) contents (table 4).

On the other hand, the potassium content in ash showed a positive correlation with sum total of days from seeding to flowering, from flowering to maturity, and from seeding to maturity, accumulated daily mean temperature from seeding to flowering, from flowering to maturity, and from seeding to maturity, accumulated sunshine hours from seeding to flowering (except Ishioka), from flowering to maturity, and from seeding to maturity, and amount of totalized precipitation from seeding to flowering, from flowering to maturity (except Ishioka,) and from seeding to maturity at Ishioka and Shiojiri. At Kumamoto, only a negative correlation was observed with amount of totalized precipitation from flowering to maturity, and from seeding to maturity. At 3 whole locations, a positive correlation was also observed with sum total of days from seeding to flowering, accumulated daily mean temperature from seeding to flowering, and accumulated sunshine hours from seeding to flowering. With amount of totalized precipitation from seeding to flowering, from flowering to maturity, and from seeding to maturity, a negative correlation was observed. With weight of seed per plant, a positive correlation was observed at Ishioka, Shiojiri, and 3 whole locations, and a positive correlation was also observed with weight of 1000 seeds at Ishioka and Shiojiri. The above-mentioned

positive correlations at Ishioka and Shiojiri were also found between oil or carbohydrate content and seed characters or climatic environments in the previous paper⁶⁾. Therefore, it is considered that oil, carbohydrate, and potassium have the same tendency of the accumulation at time of maturity in the seeds. Namely, on the chemical constituents, the potassium content was correlated positively with oil and carbohydrate contents, and negatively with protein, ash, phosphorus, magnesium, and calcium contents (table 5). It is obvious that the influence of environment on the potassium content is different from that of phosphorus, magnesium, and calcium contents by reference to table 4 and 5.

2. Phosphorus.

a. Variation in phosphorus content: The phosphorus content on dry matter basis varied from 0.512 to 0.715% (mean: 0.5981%) at Ishioka, from 0.446 to 0.705% (mean: 0.5508%) at Shiojiri, and from 0.667 to 0.846% (mean: 0.7575%) at Kumamoto (table 1 and 3). The mean phosphorus value of Kumamoto is larger than that of any other location. But the coefficient of variation of Kumamoto (7.42%) is smaller than that of Ishioka (8.33%) or Shiojiri (10.91%) (table 3). Cartter and Hopper²⁾ have reported that the phosphorus in the seeds, among the 10 varieties and strains grown during 5 seasons from 1936 to 40, ranged from 0.419 to 0.822% (mean: 0.659%).

The phosphorus content in ash varied from 9.3 to 12.9% (mean: 10.69%) at Ishioka, from 8.9 to 11.7% (mean: 10.58%) at Shiojiri, and from 10.9 to 13.7% (mean: 12.24%) at Kumamoto (table 3). The samples of Kumamoto showed not only a high ash content but also a high phosphorus content in ash. However, the coefficient of variation did not significantly vary among each location (table 3).

b. Correlation with cultural conditions and chemical constituents: Regarding correlation between the phosphorus content on dry matter basis and the estimated characters or climatic environments at Shiojiri and 3 whole locations, a negative correlation was observed with sum total

Table 4. Correlation coefficients between mineral composition on dry constituents, or mineral component pairs in thirty varieties

Constituent††	Location	K				P	
		Ishioka	Shiojiri	Kumamoto	3 whole locations	Ishioka	Shiojiri
Sum total of growing days	{SF†	-0.122	-0.091	-0.061	0.001	-0.253	-0.455*
	{FM	-0.014	0.104	-0.188	-0.092	-0.315	-0.437*
	{SM	-0.047	0.049	-0.169	-0.069	-0.311	-0.467**
Accumulated daily mean temperature (°C)	{SF	-0.122	-0.089	-0.063	-0.047	-0.232	-0.464**
	{FM	0.031	0.088	-0.220	-0.147	-0.377*	-0.464**
	{SM	0.030	0.009	-0.197	-0.151	-0.350	-0.518**
Accumulated sunshine hours (h)	{SF	-0.136	-0.063	-0.107	-0.078	-0.114	-0.421*
	{FM	-0.042	0.135	-0.211	-0.237	-0.277	-0.438*
	{SM	-0.061	0.057	-0.202	-0.219	-0.260	-0.471**
Amount of totalized precipitation (mm)	{SF	-0.033	-0.217	0.010	-0.097	-0.338	-0.569**
	{FM	-0.067	0.145	-0.508**	-0.185	-0.233	-0.414*
	{SM	-0.065	0.084	-0.416*	-0.173	-0.265	-0.478**
Weight of seed per plant		0.054	0.005	0.200	0.011	-0.713**	-0.626**
Weight of 1000 seeds		-0.041	0.071	0.067	-0.070	-0.339	-0.310
Protein††		-0.145	0.268	0.338	0.060	0.531**	0.733**
Oil††		0.250	-0.128	-0.121	0.020	-0.609**	-0.680**
Carbohydrate††		-0.020	-0.339	-0.359*	-0.119	-0.362*	-0.570**
Ash††		0.213	0.562**	0.492**	0.231	0.700**	0.801**
K††						-0.012	0.362*
P††							
Mg††							

* Significant at the 5% level. ** Significant at the 1% level.

† The abbreviations used are: SF, seeding to flowering; FM, flowering to maturity; SM, seeding

of days from seeding to flowering, accumulated daily mean temperature from seeding to flowering, accumulated sunshine hours from seeding to flowering. At Shiojiri, a negative correlation was also observed with other environments. On the other observations, a positive correlation was observed with amount of totalized precipitation from seeding to flowering, from flowering to maturity, and from seeding to maturity at 3 whole locations. But at Kumamoto, a positive correlation was observed with sum total of days from flowering to maturity and from seeding to maturity, accumulated daily mean temperature from flowering to maturity, and from seeding to maturity, and accumulated sunshine hours from flowering to maturity and from seeding to maturity. High negative correlation was observed between the phosphorus content and weight of seed per plant

at each location and 3 whole locations. The above-mentioned negative correlations at Shiojiri and 3 whole locations were also found between protein or ash content and seed characters or climatic environments in the previous paper⁶⁾. Therefore, it is considered that protein, ash, and phosphorus have same tendency of the accumulation at time of maturity in the seeds. Namely, on the correlation between the phosphorus content and chemical constituents, a positive correlation was observed with ash content at Ishioka, Shiojiri, Kumamoto, and 3 whole locations, and with protein and magnesium contents at Ishioka, Shiojiri, and 3 whole locations, and with calcium content at Shiojiri, Kumamoto, and 3 whole locations. A negative correlation was observed between the phosphorus content and oil content at Ishioka and Shiojiri or carbohydrate content at Ishioka, Shio-

matter basis and seed characters, climatic environments, chemical of soybean seeds grown at three locations.

Mg					Ca				
Kumamoto	3 whole locations	Ishioka	Shiojiri	Kumamoto	3 whole locations	Ishioka	Shiojiri	Kumamoto	3 whole locations
0.094	-0.735**	-0.491**	-0.303	-0.235	-0.653**	-0.488**	-0.602**	-0.089	-0.682**
0.474**	0.076	-0.436*	-0.303	-0.340	-0.209	-0.317	-0.515**	0.202	0.045
0.414*	-0.260	-0.473**	-0.320	-0.335	-0.440*	-0.384*	-0.571**	0.148	-0.260
0.108	-0.651**	-0.469**	-0.307	-0.224	-0.598**	-0.502**	-0.606**	-0.078	-0.667**
0.474**	0.477**	-0.472**	-0.291	-0.343	0.097	-0.192	-0.483**	0.217	0.414*
0.419*	0.122	-0.513**	-0.333	-0.335	-0.189	-0.339	-0.602**	0.164	0.059
0.063	-0.741**	-0.348	-0.280	-0.263	-0.535**	-0.528**	-0.569**	-0.087	-0.815**
0.407*	0.214	-0.408*	-0.282	-0.327	0.039	-0.389*	-0.456**	0.177	-0.055
0.369*	-0.205	-0.416*	-0.308	-0.328	-0.236	-0.432*	-0.551**	0.145	-0.447*
0.111	0.662**	-0.576**	-0.313	-0.206	0.400*	-0.416*	-0.670**	-0.111	0.461**
0.214	0.804**	-0.333	-0.230	-0.178	0.541**	-0.423*	-0.411*	0.338	0.682**
0.228	0.802**	-0.394*	-0.264	-0.243	0.530**	-0.446*	-0.495**	0.228	0.660**
-0.680**	-0.811**	-0.617**	-0.437*	0.173	-0.534**	0.243	-0.550**	-0.328	-0.741**
0.203	-0.127	-0.394*	-0.170	-0.201	-0.212	-0.392*	-0.459**	-0.105	-0.259
-0.079	0.554**	0.698**	0.402*	0.379*	0.610**	-0.056	0.410*	-0.021	0.275
0.111	-0.051	-0.585**	-0.261	-0.213	-0.173	0.323	-0.148	0.106	0.269
-0.102	-0.727**	-0.625**	-0.403*	-0.339	-0.685**	-0.227	-0.515**	-0.135	-0.602**
0.516**	0.885**	0.715**	0.456**	0.557**	0.739**	0.356*	0.558**	0.379*	0.784**
-0.046	-0.012	-0.098	0.102	0.134	-0.000	-0.000	0.110	-0.384*	-0.104
		0.738**	0.459**	0.111	0.692**	-0.093	0.383*	0.551**	0.739**
						0.141	0.490**	0.257	0.550**

to maturity. †† % on dry matter basis.

jiri, and 3 whole locations. Among these correlations, a high positive correlation was observed between the phosphorus and ash contents of the seeds at each location and 3 whole locations (table 4). From these observations, it may be inferred that the phosphorus content in the soybean seeds is affected by the accumulation of ash. In the previous experiment, we have reported the reason for varying the ash content⁶⁾. From the result in this paper, it is observed that the variation of phosphorus content is due to the same reason. Namely, there is the high negative correlation between phosphorus content on dry matter basis and weight of seed per plant. Therefore, the variation of phosphorus content in the seeds may be due to the distribution of phosphorus contained in the plant.

On the other hand, on the correlation between

the phosphorus content in ash and estimated characters or climatic environments, a negative correlation was observed with sum total of days from seeding to flowering, accumulated daily mean temperature from seeding to flowering, accumulated sunshine hours from seeding to flowering, and a positive correlation was observed with accumulated daily mean temperature from flowering to maturity, and accumulated sunshine hours from flowering to maturity, and amount of totalized precipitation from seeding to flowering, from flowering to maturity, and from seeding to maturity at 3 whole locations. At Kumamoto, a positive correlation was observed with sum total of days from flowering to maturity and from seeding to maturity, accumulated daily mean temperature from flowering to maturity, and from seeding to maturity, accumulated sunshine hours

Table 5. Correlation coefficients between mineral composition in ash or mineral component pairs in thirty varieties of soybean

Constituent†††	Location	K				P	
		Ishioka	Shiojiri	Kumamoto	3 whole locations	Ishioka	Shiojiri
Sum total of growing days	SF†	0.375*	0.457**	0.039	0.646**	0.080	-0.216
	FM	0.415*	0.684**	-0.162	0.055	-0.051	-0.200
	SM	0.422*	0.651**	-0.125	0.321	-0.013	-0.216
Accumulated daily mean temperature (°C)	SF	0.370*	0.461**	0.036	0.587**	0.104	-0.227
	FM	0.428*	0.693**	-0.195	-0.320	-0.161	-0.216
	SM	0.442*	0.658**	-0.155	-0.013	-0.065	-0.247
Accumulated sunshine hours (h)	SF	0.319	0.449*	-0.004	0.608**	0.219	-0.198
	FM	0.395*	0.705**	-0.172	-0.119	0.011	-0.217
	SM	0.399*	0.654**	-0.153	0.211	0.050	-0.228
Amount of totalized precipitation (mm)	SF	0.477**	0.391*	0.107	-0.478**	-0.019	-0.312
	FM	0.347	0.648**	-0.533**	-0.690**	0.040	-0.239
	SM	0.389*	0.647**	-0.390*	-0.670**	0.032	-0.272
Weight of seeds per plant		0.377*	0.640**	0.216	0.633**	-0.615**	-0.424*
Weight of 1000 seeds		0.392*	0.503**	-0.005	0.207	-0.076	-0.118
Protein††		-0.517**	-0.521**	0.194	-0.445*	0.359*	0.416*
Oil††		0.499**	0.491**	-0.126	0.041	-0.558**	-0.497**
Carbohydrate††		0.412*	0.377*	-0.138	0.566**	-0.099	-0.224
Ash††		-0.542**	-0.396*	0.167	-0.614**	0.252	0.367*
K†††						-0.251	-0.287
P†††							
Mg†††							

* Significant at the 5% level. ** Significant at the 1% level.

† The abbreviations used are: SF, seeding to flowering; FM, flowering to maturity; SM, seeding

from flowering to maturity and from seeding to maturity, and amount of totalized precipitation from flowering to maturity and from seeding to maturity. With weight of seed per plant, a negative correlation was observed at Ishioka, Shiojiri, Kumamoto, and 3 whole locations. With weight of 1000 seeds, a positive correlation was observed at Kumamoto. On the correlation between the phosphorus content in ash and other chemical constituents, a negative correlation was observed with oil content at Ishioka and Shiojiri, and carbohydrate content at 3 whole locations. At Ishioka, Shiojiri, and 3 whole locations, a positive correlation was observed with protein content. At Kumamoto, however, a negative correlation was observed with protein content. At Kumamoto and 3 whole locations, a negative correlation was observed with potassium content in

ash, and a positive correlation was observed with calcium content in ash, but at Ishioka, a negative correlation was also observed with calcium content in ash. With magnesium content in ash, a positive correlation was observed at Ishioka. In the above-mentioned results, a high positive correlation was also observed between the phosphorus content on dry matter basis and protein content at Ishioka, Shiojiri, and 3 whole locations (table 4). Therefore, it is considered that the accumulation of the phosphorus in the seeds is almost similar to that of protein. Togari *et al.*⁷⁾ showed the same relationship between the phosphorus and protein accumulation in the growing plant.

3. Magnesium.

a. Variation in magnesium content: The magnesium content on dry matter basis varied

and seed characters, climatic environments, chemical constituents, seeds grown at three locations.

Mg					Ca				
Kumamoto	3 whole locations	Ishioka	Shiojiri	Kumamoto	3 whole locations	Ishioka	Shiojiri	Kumamoto	3 whole locations
0.329	-0.527**	-0.219	0.147	-0.079	0.022	-0.282	-0.460**	-0.021	-0.576**
0.668**	0.216	-0.204	0.147	-0.286	-0.125	-0.125	-0.374*	0.263	0.089
0.628**	-0.064	-0.218	0.155	-0.255	-0.085	-0.178	-0.421*	0.213	-0.181
0.341	-0.425*	-0.195	0.145	-0.072	0.066	-0.301	-0.463**	-0.012	-0.578**
0.677**	0.532**	-0.273	0.183	-0.280	-0.166	-0.001	-0.322	0.283	0.414*
0.640**	0.274	-0.265	0.185	-0.249	-0.117	-0.127	-0.430*	0.233	0.100
0.321	-0.526**	-0.074	0.139	-0.088	0.231	-0.356*	-0.439*	-0.009	-0.756**
0.623**	0.362*	-0.163	0.159	-0.242	0.150	-0.200	-0.313	0.248	-0.090
0.597**	0.015	-0.154	0.165	-0.227	0.229	-0.238	-0.400*	0.219	-0.444*
0.320	0.644**	-0.297	0.195	-0.074	-0.020	-0.193	-0.491**	-0.055	0.389*
0.396*	0.721**	-0.088	0.159	-0.057	-0.037	-0.255	-0.287	0.426	0.601**
0.476**	0.729**	-0.129	0.179	-0.081	-0.035	-0.259	-0.350	0.326	0.578**
-0.775**	-0.703**	-0.496**	0.056	0.222	0.159	0.452*	-0.378*	-0.348	-0.677**
0.395*	0.030	-0.140	0.177	-0.092	0.078	-0.203	-0.351	-0.062	-0.234
-0.409*	0.422*	0.568**	-0.260	0.165	0.160	-0.267	0.122	-0.133	0.134
0.205	-0.098	-0.501**	0.265	-0.175	-0.209	0.503**	0.113	0.150	0.352
0.304	-0.505**	-0.451*	0.195	-0.032	-0.019	-0.022	-0.283	-0.007	-0.474**
-0.154	0.604**	0.286	-0.365*	-0.017	-0.145	0.002	0.222	0.150	0.636**
-0.409*	-0.649**	-0.434*	-0.033	-0.177	-0.094	-0.103	-0.348	-0.661**	-0.665**
		0.528**	0.033	-0.255	0.041	-0.470**	-0.056	0.413*	0.447*
						-0.153	0.258	0.058	-0.162

to maturity. †† % on dry matter basis. ††† % in ash.

from 0.212 to 0.308% (mean: 0.2443%) at Ishioka, from 0.213 to 0.296% (mean: 0.2399%) at Shiojiri, and from 0.234 to 0.328% (mean: 0.2776%) at Kumamoto (table 1 and 3). On the mean value, Kumamoto showed the highest among 3 locations.

The magnesium content in ash varied from 3.82 to 5.03% (mean: 4.348%) at Ishioka, from 3.69 to 5.14% (mean: 4.621%) at Shiojiri, from 3.97 to 5.25% (mean: 4.479%) at Kumamoto (table 2 and 3). It is found that Kumamoto shows the highest magnesium content among the locations. Regarding coefficient of variation of mineral constituents, the magnesium is the smallest among the mineral constituents as shown in table 3.

b. Correlation with cultural conditions and chemical constituents: On the correlation of the magnesium content on dry matter basis with

estimated characters and climatic environments, a negative correlation was observed with sum total of days from seeding to flowering, accumulated daily mean temperature from seeding to flowering at Ishioka and 3 whole locations. At 3 whole locations, a negative correlation was also observed with accumulated sunshine hours from seeding to flowering. At Ishioka, a negative correlation was also observed with sum total of days from flowering to maturity and from seeding to maturity, accumulated daily mean temperature from flowering to maturity and from seeding to maturity, and accumulated sunshine hours from flowering to maturity and from seeding to maturity. At Ishioka, a negative correlation was observed with amount of totalized precipitation from seeding to flowering and from seeding to maturity. With amount of totalized precipitation, a positive

correlation was observed from seeding to flowering, from flowering to maturity, and seeding to maturity at 3 whole locations. With weight of seed per plant, a negative correlation was observed at Ishioka, Shiojiri, and 3 whole locations. At Ishioka, a negative correlation was observed with weight of 1000 seeds. On the chemical constituents, a positive correlation was observed with protein and ash contents at each location and 3 whole locations, and a negative correlation was observed with oil content at Ishioka, and with carbohydrate content at Ishioka, Shiojiri, and 3 whole locations. In the previous experiment⁶⁾, we have observed a negative correlation between climatic environments and protein or ash content, and a positive correlation between climatic environments and oil or carbohydrate content. Therefore, it may be considered that magnesium content is correlated positively with protein and ash contents and negatively with oil and carbohydrate contents. From the result of high correlation between magnesium and ash contents, high magnesium content on dry matter basis at Kumamoto may be due to the high ash content. With phosphorus content, a positive correlation was observed at Ishioka, Shiojiri, and 3 whole locations, and with calcium content, a positive correlation was also observed at Shiojiri and 3 whole locations (table 4).

The magnesium content in ash showed no correlation among all tested environmental factors and was constant at each location and 3 whole locations. From the results, the magnesium content in ash of soybean seeds may be a fundamental unit. On the other observations, a positive correlation was observed with protein content and phosphorus content in ash, and a negative correlation with weight of seed per plant, oil, carbohydrate contents, and potassium content in ash at Ishioka. At Shiojiri, a negative correlation was observed with ash content (table 5).

4. Calcium.

a. Variation in calcium content: The calcium content on dry matter basis was found to vary from 0.225 to 0.388% (mean: 0.2907%) at Ishioka,

from 0.126 to 0.263% (mean: 0.1872%) at Shiojiri, from 0.205 to 0.524% (mean: 0.3609%) at Kumamoto (table 1 and 3). The mean calcium value of Shiojiri is smaller than that of the other locations (table 3). The coefficient of variation of the calcium is the largest among the mineral constituents. The coefficient of variation of calcium at Ishioka (12.76%) was smaller than that of any other location, *i.e.* Shiojiri: 17.04% and Kumamoto: 20.17% (table 3). Borst and Thatcher¹⁾ have found that the calcium content in the seeds varied from 0.18 to 0.32%. Cartter and Hopper²⁾ have reported that the calcium content varied from 0.163 to 0.470% with a mean value of 0.275% on 10 soybean varieties at 5 locations for 5 years.

The calcium content in ash was from 4.33 to 6.76% (mean: 5.180%) at Ishioka, from 2.50 to 4.48% (mean: 3.593%) at Shiojiri, and from 3.73 to 8.66% (mean: 5.816%) at Kumamoto respectively (table 2 and 3). At Shiojiri, the calcium content in ash was smaller as compared with other two locations (table 3). The coefficient of variation of Kumamoto (19.22%) is larger than that of Ishioka (11.95%) or Shiojiri (14.47%), as shown in table 3.

b. Correlation with cultural conditions and chemical constituents: Regarding to correlation between the calcium content on dry matter basis and estimated characters or climatic environments, a negative correlation was observed with sum total of days from seeding to flowering, accumulated daily mean temperature from seeding to flowering, accumulated sunshine hours from seeding to flowering at Ishioka, Shiojiri, and 3 whole locations. With sum total of days from flowering to maturity and from seeding to maturity, accumulated daily mean temperature from flowering to maturity and from seeding to maturity, accumulated sunshine hours from flowering to maturity and seeding to maturity, a negative correlation was also observed at Shiojiri, and with accumulated sunshine hours from flowering to maturity and seeding to maturity, a negative correlation was also observed at Ishioka (table 4). Cartter and Hopper²⁾ have reported that temper-

ature levels significantly influenced on the calcium content of the seeds produced by a given variety. From our experiment, the high calcium value at Kumamoto was also dependent on high temperature. With amount of totalized precipitation from seeding to flowering, from flowering to maturity, and from seeding to maturity, a negative correlation was observed at Ishioka and Shiojiri, but at 3 whole locations, a positive correlation was observed with amount of totalized precipitation from seeding to flowering, from flowering to maturity, and from seeding to maturity. With weight of seed per plant, a negative correlation was observed at Shiojiri and 3 whole locations, and with weight of 1000 seeds, a negative correlation was also observed at Ishioka and Shiojiri. Between the calcium content and chemical constituents, a negative correlation was observed with carbohydrate content at Shiojiri and 3 whole locations and potassium content at Kumamoto, and a positive correlation was observed with protein content at Shiojiri, ash content at Ishioka, Shiojiri, Kumamoto, and 3 whole locations, phosphorus content at Shiojiri, Kumamoto and 3 whole locations, and magnesium content at Shiojiri and 3 whole locations (table 4). From the result of the high positive correlation between ash and calcium contents on dry matter basis, the high calcium content on dry matter basis at Kumamoto may be due to the high ash content.

On the correlation between the calcium content in ash and estimated characters or climatic environments, much the same correlations observed on the calcium content on dry matter basis were shown at Shiojiri and 3 whole locations. On the chemical constituents, a positive correlation was observed with oil content at Ishioka, ash content at 3 whole locations, and phosphorus content in ash at Kumamoto and 3 whole locations, and a negative correlation was observed with carbohydrate content at 3 whole locations, potassium content in ash at Kumamoto and 3 whole locations, and phosphorus content in ash at Ishioka (table 5).

From the above-mentioned results, we found

the following characteristics of mineral constituents of soybean seeds at 3 locations. Regarding the coefficient of variation, both the calcium values on dry matter basis and in ash were the largest. On the mean value on dry matter basis, the location variance was observed in phosphorus, magnesium, and calcium contents, but not observed in potassium content. Namely, phosphorus, magnesium, and calcium contents were high at Kumamoto. On the mean value in ash, however, the location variance was observed in potassium, phosphorus, magnesium, and calcium contents at 3 locations. Namely, phosphorus and calcium contents were high, and potassium content was low at Kumamoto.

On the correlation between climatic environments and mineral constituents on dry matter basis, a negative correlation was observed in phosphorus, magnesium, and calcium contents, and no correlation was observed in potassium content at Ishioka and Shiojiri. In the previous experiment⁶⁾, the same correlation was observed between ash content and climatic environments at Ishioka and Shiojiri. It is, therefore, considered that there is a high positive correlation between ash content and phosphorus, magnesium, and calcium contents on dry matter basis. From those observations, it can be inferred that the ash content affects especially the phosphorus, magnesium, and calcium contents in soybean seeds. On the other hand, the correlation between climatic environments and mineral constituents in ash was different from the above-mentioned results. Namely, a positive correlation was observed in potassium content and no correlation was observed in magnesium content. The magnesium content in ash was constant. From these results, the magnesium content in ash of soybean seeds may be fundamental unit.

SUMMARY

The seeds of 30 soybean varieties grown at 3 locations, *i.e.* Ishioka, Shiojiri, and Kumamoto, were analyzed for potassium, phosphorus, magnesium, and calcium contents. On the location

variance, the mean value on dry matter basis, the potassium content was not observed among 3 locations, but the phosphorus, magnesium, and calcium contents varied at each location. Namely, Kumamoto showed the highest in phosphorus, magnesium, and calcium contents among the locations. On the mean value in ash, the potassium, phosphorus, magnesium, and calcium contents differed at each location. Regarding the coefficient of variation, both the calcium values on dry matter basis and in ash were the largest. On the correlation between the mineral content on dry matter basis and estimated characters or climatic environments, there is no correlation in potassium content at Ishioka, Shiojiri, and Kumamoto, and is a negative correlation in phosphorus, magnesium, and calcium contents at Ishioka and Shiojiri. With weight of seed per plant, there is high negative correlation in phosphorus content at 3 locations. On the correlation between the mineral content in ash and estimated characters or climatic environments, there is a positive correlation in potassium content and no correlation in magnesium content at 3 locations, and is a negative correlation in calcium content at Shiojiri. At Kumamoto, however, different correlation was observed between mineral constituents and estimated characters or climatic environments. On the chemical constituents on dry matter basis, the potassium content showed a positive correlation with ash and phosphorus contents and a negative correlation with carbohydrate and calcium contents. The phosphorus content showed a positive correlation with protein, ash, magnesium, and calcium contents, and a negative correlation with oil and carbohydrate contents. The magnesium content showed a positive correlation with protein, ash, phosphorus, and calcium contents, and a negative correlation with carbohydrate and oil contents. The calcium content showed a positive correlation with protein, ash, phosphorus, and magnesium contents, and a negative correlation with carbohydrate and protein contents. Regarding the relation between minerals in ash and other chemical constituents on dry

matter basis, the potassium content showed a positive correlation with oil and carbohydrate contents, and a negative correlation with protein, ash, phosphorus, magnesium, and calcium contents. The phosphorus content showed a positive correlation with protein, ash, magnesium, and calcium contents, and a negative correlation with oil, carbohydrate, and potassium contents. The magnesium content showed a positive correlation with protein and phosphorus contents, and a negative correlation with oil, carbohydrate, ash, and potassium contents. The calcium content showed a positive correlation with oil, ash, and phosphorus contents, and a negative correlation with carbohydrate, and potassium contents.

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LITERATURE CITED

1. BORST, H. L. and L. E. THATCHER 1931. Life history and composition of the soybean plant. Ohio Agr. Expt. Sta. Bull. 494, 96 pp.
2. CARTTER, J. L. and T. H. HOPPER 1942. Influence of variety, environment, and fertility level on the chemical composition of soybean seed. U. S. Dept. Agr. Tech. Bull. No. 787, 66 pp.
3. KUBO, S. and C. TSUTSUMI 1951. Determination of calcium in food. Shokuryo Kenkyusho Kenkyu Hokoku No. 5: 171—176. [in Japanese]
4. NAKAMURA, M. 1950. Colorimetric determination of phosphorus. J. Agr. Chem. Soc. Japan 24: 1—5. [in Japanese]
5. SMIRNOVA, M. I. and M. N. LAVROVA 1934. Variation of the chemical composition in different soybean varieties. Trudy Prikl. Bot., Genet., i Selekt. (Bul. Appl. Bot., Genet., and

- Plant Breeding), Ser. III, No. 5, 103 pp., illus. In Russian English Summary, p. 103.
6. TAIRA, H. and H. TAIRA 1971. Influence of location on the chemical composition of soybean seeds. I. Protein, oil, carbohydrate, and ash contents. Proc. Crop Sci. Soc. Japan 40: 530—544.
7. TOGARI, Y., Y. KATO and M. EBATA 1955. Studies on the yield analysis of soybean. (I) Changes in principal chemical constituents of the soybean plant in relation to its growth. Proc. Crop. Sci. Soc. Japan 24: 103—107. [in Japanese]
8. VILJOEN, N. J. 1937. An investigation into the composition of the soybean in South Africa. Union So. Africa Dept. Agr. and Forestry Sci. Bull. No. 169, 68 pp.

〔和 文 摘 要〕

大豆の化学成分組成と栽培地の関係について

第2報 カリ・リン・マグネシウムおよびカルシウム含量

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大豆の30品種を石岡・塩尻および熊本の大豆育種試験地の圃場でそれぞれ栽培し、得られた大豆について、カリ、リン、マグネシウムおよびカルシウムの含量をしらべた。これら種子の無機成分含量と、各地域における生育特性（開花まで、登熟および成熟までの日数）、栽培環境（開花まで、登熟および成熟までの積算平均気温、積算日照時間、積算降水量）、一株粒重、千粒重および一般成分（タンパク質、脂質、炭水化物、灰分）などとの関係について検討を加えた。

これら栽培地を異にした大豆の無機成分含量の地域的変動は乾物中の含量において、カリは石岡、塩尻、熊本間に変動が認められないが、リン、マグネシウム、カルシウムは三地域間において変動が認められた。一方、これら無機成分の灰分中の含量においては、カリ、リン、マグネシウム、カルシウムにおいて地域的変動が認められた。これら無機成分含量の品種間の変動は、乾物中および灰分中のカルシウムの変動が、カリ、リン、マグネシウムの変動に比べて大きいことが認められた。

これら無機成分含量の変動におよぼす生育特性・栽培環境との相関は、石岡、塩尻および3地域総合において同じ傾向を示した。すなわち、乾物中の含量においてはカリとの間には相関が認められないが、リン、マグネシウム、カルシウムとの間に負の相関が認められた。一方、灰分中の含量においては、カリが前記条件との間に正の、リン、カルシウムにおいて負の相関が認められた。なお、マグネシウムにおいては、これら上記諸要因との間に全く相関が認められなかつた。また、これら上記の諸相関は、熊本においては異なつた傾向が認められた。

一般成分含量と無機成分含量間の相関は、石岡、塩尻、熊本および3地域総合においてほとんど同じ傾向が認められた。すなわち、カリが炭水化物との間に負の、灰分との間に正の相関が認められ、リン、マグネシウムにおいては、タンパク質、灰分との間に正の相関が、脂質、炭水化物との間に負の相関が認められた。また、カルシウムにおいては、タンパク質、灰分との間に正の、炭水化物との間に負の相関が認められた。また、無機成分含量間の相関では、カリがリンとの間に正の、カルシウムとの間に負の、リンがマグネシウム、カルシウムとの間に正の、マグネシウムがカルシウムとの間に正の各相関が認められた。一方、灰分中の各無機成分含量と一般成分含量との間の相関は、カリにおいてはタンパク質、灰分との間に負の、脂質、炭水化物との間に正の、リンにおいては、タンパク質、灰分との間に正の、脂質、炭水化物との間に負の相関がそれぞれ認められた。また、マグネシウムにおいては、タンパク質との間に正の、脂質、炭水化物、灰分との間に負の、カルシウムにおいては、灰分、脂質との間に正の、炭水化物との間に負の相関がそれぞれ認められた。また、灰分中各無機成分含量間の相関においては、カリはリン、マグネシウム、カルシウムとの間に負の、リンはマグネシウム、カルシウムとの間に正の各相関が認められた。