Variations of Growth-Period of Italian Millet Strains, *Setaria italica* BEAUV. and their Responses to Day-Length and Temperature

II. Changes of Growth-Period of Strains Gathered from Different Districts, Both Native and Foreign, due to the Different Seeding Dates

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Introduction

Generally, it is recognized that *Setaria italica* consists of two main varieties, Italian millet, Ooawa or Awa in Japanese, *Setaria italica* BEAUV. var. *Maximum* AL. and German millet, Koawa in Japanese, *Setaria italica* BEAUV. var. *Germanicum* TRIN., the former having long, large and hanged panicle and the later short, small and erect one, and that all varieties under cultivating in Japan are Italian millet, but not German millet [5,8,9].

However, as the above mentioned characters taken up as the keys of discrimination between the two varieties are easily variable under different cultivating conditions, so it seems to be difficult to discriminate the two varieties only by those characters.

In addition to above mentioned varieties, several names of varieties are listed up by Tanaka: namely, var. *nigrofructa* BAIL., Hungarian-grass; var. *rubrofructa* BAIL., Siberian millet, Turkestan millet; var. *stramineofructa* BAIL., German millet, Golden Wonder millet.

Now, in our laboratory, about 500 strains of this crop gathered from different districts, both native and foreign, have been reserved. Those are made up of the varieties gathered from Europe, China, Korea and Africa, which were spared to our laboratory from Dr. Kuckuck and Dr. Michaelis in Germany and Plant Industry, Leningrad, U.S.S.R., the varieties spared from Korean Agricultural Station and Indian Agricultural Reseach Institute, the varieties gathered from Formosa by Dr. Oka, the varieties gathered from India by Dr. Katayama, the varieties gathered from Philippines by Prof. Miyaji and the local varieties gathered from different districts in Japan by the authors, with favourable assistance of the members of agricultural experiment stations and the agricultural agents in the respective prefectures. It is inferred that a number of German millet varieties may be involved in the varieties from Europe.

In this laboratory, the seed production culture of the gathered varieties, with different seeding dates, was conducted yearly and the heading dates of the respective varieties were recorded during several years, the leaf-numbers of main stem also recorded for a year.

Basing of these records, the varietal variations of growth-period and thier responses to day-length and temperature, in special reference to their gathered districts, are discussed in this paper.

The authors are grateful to the above mentioned persons from whom we were spared many varieties. We are also grateful to the members of our laboratory for their cooperation in many ways.

Material and Method

One hundred and twenty-six varieties were picked out from about five hundred strains gathered from different districts, both native and foreign, and used in this experiment. They were seeded in field on 22 July in 1967, on 8 July in 1971 and on 15 June in 1972, respectively, and were seeded in pot on 6 May and 11 July in 1969.

In the case of seeding in field, after germination, plants were thinned in, about 10cm distance apart, each other, and about thirty plants of the respective variety were cultivated. Heading-date of the respective variety was determinated by the length of time on which ninety percent plants of the respective variety headed.

In the case of seeding in pot, after germination, the plants were thinned in, about 5cm distance apart, each other, and five plants of the respective varieties were cultivated in one pot. Two pots per the respective varieties were used. The heading-date and the number of leaves of main stem of all plants of the respective varieties were recorded. The whole data were illustrated by the average-value of the whole plants of the respective varieties.

The seeded pots were laid in greenhouse during the experiment.

Changes of mean temperature and natural day-length after seeding at different seeding dates are shown in Fig.1. As shown in Fig.1 the temperature in the greenhouse was higher than it was out of the door, accordingly, especially in summer, the temperature to which the plants subjected was higher in pot-cultivation than in field-cultivation.

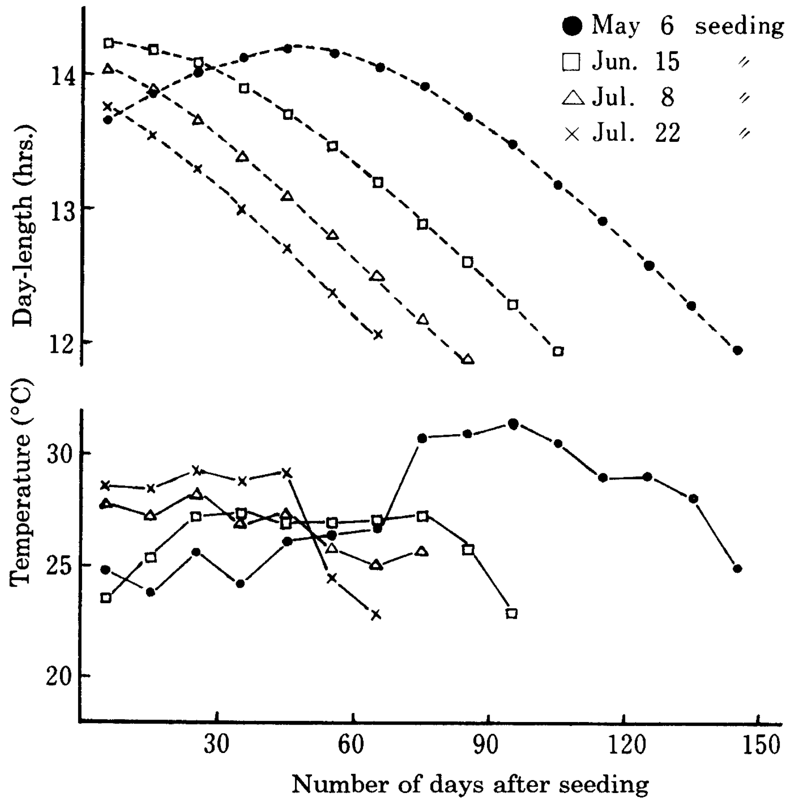

Fig. 1 Changes of the mean temperature and day-length after seeding.

Results

1. Variations of the growth-period

Frequency-distributions of the growth-period variations, in days, from seeding to heading of the respective varieties on different seeding dates, are shown in Table 1. The

Table 1. Frequency-distributions of varietal variation of growth-period at different seeding dates.

Seeding dates	Culti-vation	Number of days of growth-period 20	30	40	50	60	70	80	90	100	110	120	130	140	150	Total number of varieties
May 6 '69	pot		14	18	9	7	14	14	9	9	10	12	18	2		126
June 15 '72	field		10	26	20	20	20	10	39	1						126
July 8 '71	filed	1	21	32	17	37	18									126
July 11 '69	pot	3	34	17	20	38	14									126
July 22 '67	field	29	29	37	21	7	3									126

number of days from seeding to heading of the respective varieties generally became shorter as the seeding-dates delayed from May to July, in spite of the differences in the cultivating conditions (field and pot) and the seeding-years. Concerning the variations of growth-period among the varieties seeded on the same date, those seeded in May were largest, becoming smaller as the seeding dates became later, reaching smallest in those seeded in July.

Above mentioned results show that the seeding in July 22 gave the most favourable environment to the shortening of growth-period in almost all the varieties used in this experiment.

In order to clear the effect of day-length and temperature to the growth-periods of the varieties, notice was taken on the shortest growth-period of the respective varieties in this experiment; namely, basic vegetative growth-phase.

Frequency-distributions of geographical variation of the shortest growth-period of the respective varieties in this experiment are shown in Table 2. Almost all varieties from Europe, except two, showed the shortest growth-period counting less than 30 days, and their variations were smaller.

The varieties from Japan showed wide variations of the shortest growth-period from 20 days to 70 days, namely the varieties from Aomori, Akita, Iwate and Nagano showing shorter growth-periods, those from Nagasaki, Kumamoto, Kagoshima and Okinawa showing the growth-period from shorter to longer, the varieties from Korea, China and India showed the intermediate length and variation of the shortest growth-period. The varieties from Formosa showed the shortest growth-period similar to that of the varieties from Kagoshima in Japan.

Generally, varieties from the higher-latitude districts showed shorter growth-period than those from the lower-latitude-ones, and the varieties from the intermediate latitude districts showed wide variations of the shortest growth-period.

Relationship between the shortest and the longest growth-periods in the respective varieties in this experiment is shown in Table 3. According to the table, the shortest growth-period of the respective varieties is clearly correlated with the longest growth-period. However, if it is restricted to the range of the shortest growth-period counting more than 40 days, the relationship is not so clear; namely, the varieties showing the shortest growth-period counting more than 40 days show a comparatively wide variation

Table 2. Frequency-distributions of geographical variation of the shortest growth-period.

Districts	Latitude (N)	The shortest growth-period (days) 20	30	40	50	60	70	80	Total number of varieties
Sweden	55–60	1							1
Denmark	55–57	1							1
Poland	50–55	1							1
Germany	47–55	2							2
Austria	46–49	1							1
Swit.	46–48		1						1
Hungary	46–48	2							2
U.S.S.R.	45–60	9							9
France	43–51	1	1						2
Rumania	43–48	1							1
Bulgaria	41–44	5							5
Japan									
Aomori	40–41		1						1
Akita	39–40	1							1
Iwate	39–40		1						1
Nagano	35-37		6						6
Nara	34–35			1					1
Nagasaki	32–34			2	1	1			4
Kumamoto	32–33		3	1		4			8
Kagoshima	28–32		3	21	18	2			44
Okinawa	24–28			1	1	1			3
Korea	35–43	1	7	1					9
China	20–50	2	4						6
Formosa	21–25			6		1	1		8
India	8–30		2	3					5
Philippines	5–20	1			1				2
Africa	N35–S35			1					1
Total number of varieities		29	29	37	21	9	1		126

of the longest growth-period.

Frequency-distributions of geographical variation of the difference of growth-period between the longest and the shortest periods are shown in Table 4. Generally, the varieties from Europe showed little differences of the growth-period between the longest and the

Table 3. Relationship between the shortest and the longest growth-periods in the respective varieties.

The longest growth-period (days)	The shortest growth-period (days) 20–30	30–40	40–50	50–60	60–70	70–80	Total number of variteies
30–40	2						2
40–50	16	2					18
50–60	7	4					11
60–70	1	6					7
70–80	2	11	1				14
80–90	1	4	7	1	1		14
90–100		1	8				9
100–110			5	2	1	1	9
110–120			7	1	2		10
120–130		1	5	5		1	12
130–140			4	11	3		18
140–150				1		1	2
Total number of varieties	29	29	37	21	7	3	126

r = +0.8605 (d.f. = 124), significant at the 0.1% level.

Table 4. Frequency-distributions of geographical variation of the difference of growth-period between the longest and the shortest periods.

Districts	Latitude (N)	Difference (days) 10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	Total number of varieties
Sweden	55–60	1								1
Denmark	55–57				1					1
Poland	50–55	1								1
Germany	47–55		1	1						2
Austria	46–49		1							1
Swit.	46–48	1								1
Hungary	46–48	2								2
U.S.S.R.	45–60	4	4		1					9
France	43–51	1		1						2

Districts	Latitude (N)	Difference(days) 10	20	30	40	50	60	70	80	90	Total number of varieties
Rumania	43–48	1									1
Bulgaria	41–44	2	3								5
Japan											
Aomori	40–41			1							1
Akita	39–40				1						1
Iwate	39–40		1								1
Nagano	35–37			4	2						6
Nara	34–35			1							1
Nagasaki	32–34		1	1		2					4
Kumamoto	32–33			1	3	1	2		1		8
Kagoshima	28–32				7	1	5	15	16		44
Okinawa	24–28					3					3
Korea	35–43			5	2	2					9
China	20–50	4	2								6
Formosa	21–25		1	2	3	1	1				8
India	8–30			1	1		3				5
Philippines	5–20	1			1						2
Africa	N35–S35						1				1
Total number of varieties		18	14	18	22	10	12	15	17		126

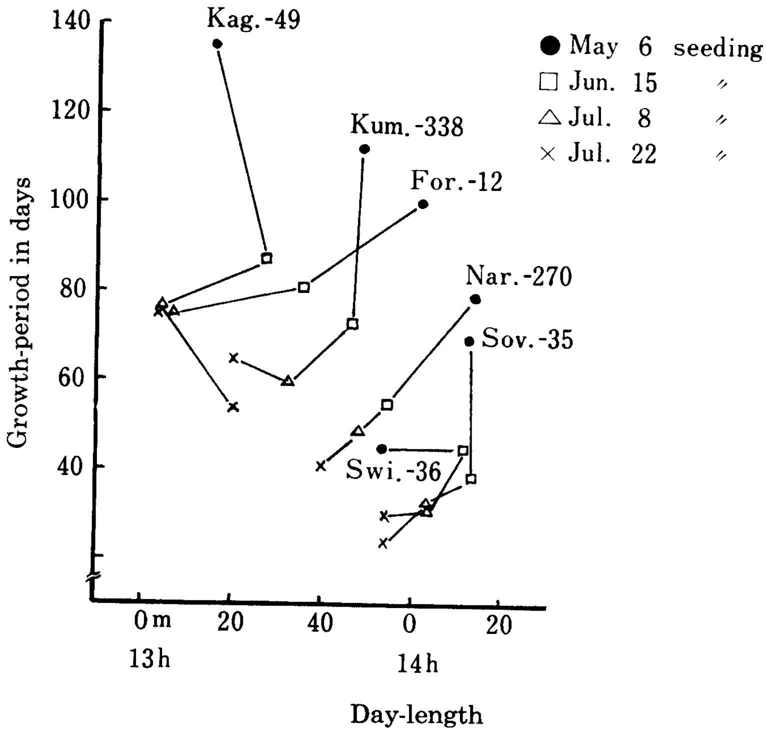

Fig. 2 Relationships between the growth period and the day-length 30 days before heading with different seeding dates in several varieties.

shortest periods, the varieties from Japan showing large differences, and the varieties from the other districts showing intermediate differences.

2. Sensitivity to day-length

Seasonal changes of day-length are an important factor affecting the variations of growth-period of the photo-sensitive varieties.

The relationships between number of days from seeding to heading and day-length 30 days before heading at different seeding dates in some varieties are shown in Fig. 2. It clearly shows that the growth-periods of some varieties were affected in various degrees by the day-length 30 days before heading, but those of others were affected little. The sensitivity to day-length and the critical day-length of the respective varieties were decided as in the previous paper[2].

Frequency-distributions of geographical variations of the sensitivity to day-length are shown in Table 5. Many varieties from Europe showed lower sensitivities, but a few of them showed extremely higher ones. The varieties from Japan and other districts showed wide range of sensitivities from lower to higher, especially, some varieties from Kagoshima, Akita, Nagano and Okinawa in Japan and some others from Formosa and India showed extremely higher sensitivities. Moreover, it was a remarkable fact that the varieties from Kagoshima contained large variations of the sensitivity to day-length.

Table 5. Frequency-distributions of geographical variation of the sensitivity to day-length.

Districts	Latitude (N)	Sensitivity 0	3	6	9	12	15	18	21	∞	Total number of varieties
Sweden	55–60		1								1
Denmark	55–57	1			1						1
Poland	50–55	1									1
Germany	47–55	1								1	2
Austria	46–49	1									1
Swit.	46–48	1									1
Hungary	46–48	2									2
U.S.S.R.	45–60	5	3						1		9
France	43–51	1	1								2
Rumania	43–48	1									1
Bulgaria	41–44		3							2	5
Japan											
Aomori	40–41			1							1
Akita	39–40								1		1
Iwate	39–40		1								1
Nagano	35–37	3	1	1						1	6
Nara	34–35	1									1
Nagasaki	32–34	1	3								4
Kumamoto	32–33	3	1	3				1			8
Kagoshima	28–32	14	12	8	1	1	1	2	1	4	44
Okinawa	24–28	1		1					1		3
Korea	35–43	3	2	4							9
China	20–50	5			1						6
Formosa	21–25	3	4						1		8
India	8–30		1	1						3	5
Philippines	5–20	2									2
Africa	N35–S35			1							1
Total number of varieties		49	33	20	3	1	1	3	5	11	126

3. Critical day-length

Frequency-distributions of the geographical variation of critical day-length for the most radical change of the growth-period are shown in Table 6. All varieties from Europe showed longer critical day-length covering over 13 hours and 50 minutes. On the other hand, the varieties from Japan showed different critical day-length from 13 hours and 10 minutes to 14 hours and 20 minutes. Especially, the varieties from Kumamoto and Kagoshima consisted of those having various critical day-lengths. The varieties from Formosa also showed longer and shorter critical day-lengths, and those from Philippines showed shorter ones.

Generally, the varieties from higher latitude districts showed longer critical day-length, the varieties from intermeditate latitude districts showing the various critical day-length, and the varieties from lower latitude districts consisting of those showing shorter critical day-lengths.

Table 6. Frequency-distributions of geographical variation of critical day-length for the most radical change of growth-period.

Districts	Latitude (N)	Day-length 13h 10m	20	30	40	50	14h 0	10	20	Total number of varieties
Sweden	55–60					1				1
Denmark	55–57							1		1
Poland	50–55						1			1
Germany	47–55					1	1			2
Austria	46–49					1				1
Swit.	46–48						1			1
Hungary	46–48							2		2
U.S.S.R.	45–60					5	3	1		9
France	43–51					1	1			2
Rumania	43–48					1				1
Bulgaria	41–44					5				5
Japan										
Aomori	40–41					1				1
Akita	39–40							1		1
Iwate	39–40						1			1
Nagano	35–37				2		3	1		6
Nara	34–35						1			1
Nagasaki	32–34			1			3			4
Kumamoto	32–33		1	3	3	1				8
Kagoshima	28–32	4	17	16	5		2			44
Okinawa	24–28	1			1	1				3
Korea	35–43			1		1	2	5		9
China	20–50					1	3	2		6
Formosa	21–25		1	1	2	1	3			8
India	8–30					3	1	1		5
Philippines	5–20	1		1						2
Africa	N35–S35					1				1
Total number of varieties		6	19	23	13	25	26	14		126

4. Sensitivity to temperature

In order to clarify the relationship between the growth-period of the respective varieties and the temperature during the period, the average temperature from seeding to heading of the respective varieties with different seeding-date was claculated.

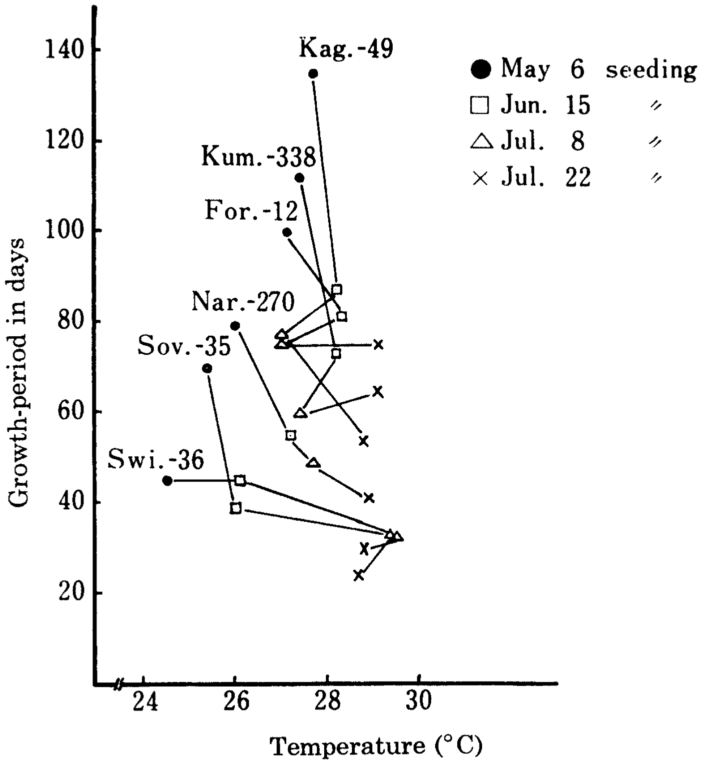

Fig. 3 Relationship between the growth period and the average temperature during the growth-period with different seeding dates in several varieties.

The relationship between the growth-period of the respective varieties and the average temperature during the period with different seeding-dates in several varieties is shown in Fig 3. It shows that the growth-period of the respective varieties was affected in various degrees by the temperature during the period. Some varieties seem to have the respective, affective temperature range for radical change of the growth-period, though it was not so clear in some varieties.

The largest value of the ratios of the difference of the growth-period between the two successive seedings to the difference of the average temperature during the period between the two was considered to have indicated the sensitivity to temperature of the respective varieties. And the mean of the two average temperatures used for claculation of the largest value was considered to be the temperature showing the largest shortening-rate of growth-period of the respective varieties. Basing on this way of thinking, sensitivity to temperature and average temperature during the growth-period showing the largest shortening rate of growth-period of the respective varieties were calculated as in the previous paper[2].

Frequency-distributions of the geographical variation of sensitivity to temperature are shown in Table 7. One variety from Europe and some from Japan, Korea and Formosa showed higher sensitivity to the average temperature during the growth-period. Generally, the varieties from higher latitude-districts showed lower sensitivity to temperature, and

Table 7. Frequency-distributions of geographical variation of the sensitivity to the average temperature during growth-period.

Districts	Latitude (N)	Sensitivity 0	10	20	30	40	50	60	70	80	Total number of varieties
Sweden	55–60		1								1
Demark	55–57			1							1
Poland	50–55		1								1
Germany	47–55		2								2
Austria	46–49	1									1
Swit.	46–48	1									1
Hungary	46–48	2									2
U.S.S.R.	45–60	2	5	1			1				9
France	43–51	1	1								2
Rumania	43–48		1								1
Bulgaria	41–44		4	1							5
Japan											
Aomori	40–41			1							1
Akita	39–40			1							1
Iwate	39–40			1							1
Nagano	35–37		2	2				1	1		6
Nara	34–35							1			1
Nagasaki	32–34		1	2						1	4
Kumamoto	32–33		5	1				2			8
Kagoshima	28–32	1	6	21	11		2			3	44
Okinawa	24–28		2	1							3
Korea	35–43	2	2	2		1	2				9
China	20–50	3	3								6
Formosa	21–25		5	1				1		1	8
India	8–30	1	4								5
Philippines	5–20		1	1							2
Africa	N35–S35		1								1
Total number of varieties		14	47	37	11	1	5	5	1	5	126

the varieties from lower latitude districts showed wide range of sensitivity from low to high. However, the relationship between the sensitivity of respective varieties and the latitude of the district in which those were gathered was not so clear as in the previous paper[2)].

Frequency-distributions of geographical variation of the average temperaure during growth-period showing the largest shortening rate of growth-period are shown in Table 8. The varieties from Europe were divided clearly into two groups concerning the average temperature during growth-period showing the largest shortening rate of growth-period; namely, some varieties from Europe showed lower temperature and the others showed higher one.

The varieties from Japan showed various temperatures according to the latitudes of the districts where those were gathered.

Table 8. Frequency-distributions of geographical variation of the average-temperature during growth-period showing the largest shortening rate of growth-period.

Districts	Latitude (N)	Temperature (°C) 25	26	27	28	29	Total number of varieties
Sweden	55–60				1		1
Denmark	55–57	1					1
Poland	50–55				1		1
Germany	47–55	2					2
Austria	46–49	1					1
Swit.	46–48			1			1
Hungary	46–48			2			2
U.S.S.R.	45–60	1		1	7		9
France	43–51	1			1		2
Rumania	43–48				1		1
Bulgaria	41–44	1			4		5
Japan							
Aomori	40–41	1					1
Akita	39–40	1					1
Iwate	39–40			1			1
Nagano	35–37		5	1			6
Nara	34–35		1				1
Nagasaki	32–34		2	1	1		4
Kumamoto	32–33	1	3	4			8
Kagoshima	28–32		32	11	1		44
Okinawa	24–28		1	2			3
Korea	35–43	1	3		5		9
China	20–50	4		1	1		6
Formosa	21–25		5		3		8
India	8–30	1		1	3		5
Philippines	5–20			1	1		2
Africa	N35–S35				1		1
Total number of varieties		16	52	27	31		126

Sensitivity to temperature and average temperature during the flower-bud-formation-period (from 35 days to 15 days before heading) showing the largest shortening rate of growth-period of the respective varieties were calculated as in the same method as in that of the total growth-period. Relationship between the growth-period and the average temperature during flower-bud-formation-period with different seeding dates in several varieties is shown in Fig 4. It shows that the growth-period of the respective varieties was

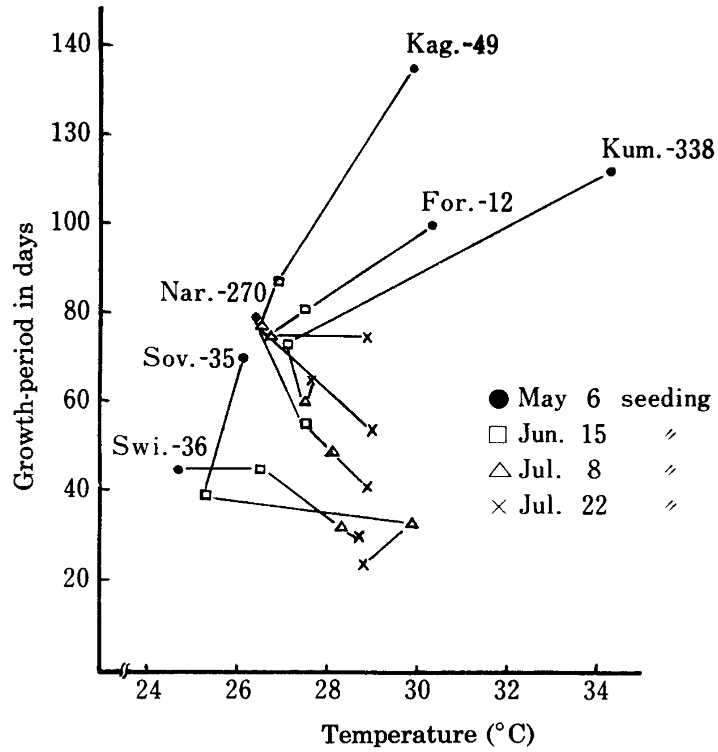

Fig. 4 Relationship between the growth-period and the average temperature during flower-bud-formation-period with different seeding dates in several varieties.

affected in various degrees by the temperature during the flower-bud-formation-period. Frequency-distributions of geographical variation of sensitivity to average temperature during flower-bud-formation-period showing the largest shortening rate of growth-period are shown in Table 9. Generally, the varieties from intermediate latitude districts, espe-

Table 9. Frequency-distributions of geographical variation of sensitivity to average-temperature during flower-bud-formation-period showing the largest shortening rate of growth-period.

Districts	Latitude (N)	Sensitivity 0	30	60	90	120	150	180	210	∞	Total number of varieties
Sweden	55–60									1	1
Denmark	55–57	1									1
Poland	50–55	1									1
Germany	47–55	1	1								2
Austria	46–49	1									1
Swit.	46–48	1									1
Hungary	46–48	2									2
U.S.S.R.	45–60	7	1	1							9
France	43–51	2									2

Districts	Latitude (N)	Sensitivity 0	30	60	90	120	150	180	210	∞	Total number of varieties
Rumania	43–48	1									1
Bulgaria	41–44	4	1								5
Japan											
Aomori	40–41	1									1
Akita	39–40	1									1
Iwate	39–40		1								1
Nagano	35–37	3	3								6
Nara	34–35	1									1
Nagasaki	32–34	2	2								4
Kumamoto	32–33	4	3	1							8
Kagoshima	28–32	17	13	2	1	2	3	2	1	3	44
Okinawa	24–28	3									3
Korea	35–43	5	3				1				9
China	20–50	3	2		1						6
Formosa	21–25	5	1			1				1	8
India	8–30	3	1	1							5
Philippines	5–20	1	1								2
Africa	N35–S35	1									1
Total number of varieties		71	33	5	2	3	4	2	1	5	126

cially, Kagoshima in Japan, Korea, China and Formosa, showed wide range of sensitivities, and one variety from Sweden showed especially high sensitivity.

Frequency-distributions of geographical variation of the average temperature during flower-bud-formation-period showing the largest shortening rate of growth-period are shown in Table 10. The varieties from Europe showed wide range of the temperature and those from Japan showed narrow one. The varieties from China also showed wide range of the temperature.

Table 10. Frequency-distributions of geographical variation of the average temperature during flower-bud-formation-period showing the largest shortening rate of growth-period.

Districts	Latitude (N)	Temperature (°C) 24	25	26	27	28	29	Total number of varieties
Sweden	55–60	1						1
Denmark	55–57			1				1
Poland	50–55					1		1
Germany	47–55		1			1		2
Austria	46–49					1		1
Swit.	46–48				1			1
Hungary	46–48			2				2
U.S.S.R.	45–60	1			2	6		9
France	43–51					2		2

Districts	Latitude (N)	Temperature (°C) 24–25	25–26	26–27	27–28	28–29	Total number of varieties
Rumania	43–48					1	1
Bulgaria	41–44					5	5
Japan							
Aomori	40–41			1			1
Akita	39–40			1			1
Iwate	39–40			1			1
Nagano	35–37				3	3	6
Nara	34–35				1		1
Nagasaki	32–34			1	2	1	4
Kumamoto	32–33				7	1	8
Kagoshima	28–32			4	31	9	44
Okinawa	24–28				2	1	3
Korea	35–43		1	3	4	1	9
China	20–50	3			1	2	6
Formosa	21–25			1	4	3	8
India	8–30				4	1	5
Philippines	5–20				1	1	2
Africa	N35–S35				1		1
Total number of varieties		5	2	15	64	40	126

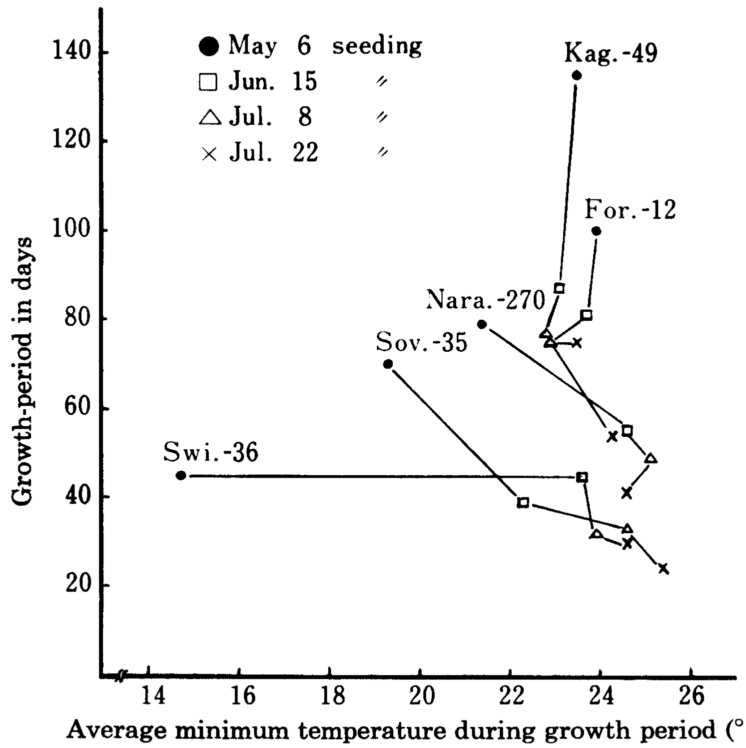

Fig. 5 Relationship between the growth period and the average minimum temperature during flower-bud-formation stage with different seeding dates in several varieties.

Basing on those results, it was inferred that the varieties from higher latitude districts consisted of those showing the flower-bud-formation in wide range of temperature from low to high, and the varieties from lower latitude districts consisted of those showing that only in higher temperature.

The night-temperature, namely dark time temperature, is considered to be important to the flower-bud-formation of plants, especially in case of photo-sensitive plants. Minimum temperature of a day was considered as an index of night-temperature. Relationship between the growth-period and the average of minimum temperature of a day during flower-bud-formation-period is as shown in Fig 5. Some varieties headed in wide range of temperature and the others only in narrow range of that. Frequency-distributions of geographical variation of the smallest mean of minimum temperature of a day during the

Table 11. Frequency-distributions of geographical variation of the smallest mean of minimum temperature during the flower-bud-formation-period at different seeding dates.

Districts	Latitude (N)	Temperature (°C) 14–16	16–18	18–20	20–22	22–24	24–26	Total number of varieties
Sweden	55–60	1						1
Denmark	55–57			1				1
Poland	50–55	1						1
Germany	47–55	2						2
Austria	46–49	1						1
Swit.	46–48	1						1
Hungary	46–48	2						2
U.S.S.R.	45–60	8		1				9
France	43–51	1	1					2
Rumania	43–48	1						1
Bulgaria	41–44	5						5
Japan								
Aomori	40–41			1				1
Akita	39–40			1				1
Iwate	39–40		1					1
Nagano	35–37		1	2	2	1		6
Nara	34–35				1			1
Nagasaki	32–34					4		4
Kumamoto	32–33			1	2	4	1	8
Kagoshima	28–32				3	41		44
Okinawa	24–28					3		3
Korea	35–43		2	1	6			9
China	20–50	6						6
Formosa	21–25					7	1	8
India	8–30		1			2	2	5
Philippines	5–20	1				1		2
Africa	N35–S35						1	1
Total number of varieties		30	6	8	14	63	5	126

flower-bud-formation-period of the respective varieties at different seeding dates are as shown in Table 11. Generally, the varieties from Europe headed in lower minimum temperature and the varieties from Japan headed in wide range of the temperature from lower to higher, according to the latitude of the gathered districts.

5. Relationship between the changes of growth-period and those of leaf-number of main stem.

Generally, it is considered that the sensitivity to temperature of the respective varieties concerning the growth-period is related with at least two different responses, namely, accelerating of growth and that of flower-bud-formation, as Oka[6] pointed out. As an index of accelerating of growth, the number of leaves of main stem was used in this experiment. Relationship between the number of leaves of main stem in the respective varieties in spring-seeding and that in summer-seeding in 1969 is shown in Table 12. This table

Table 12. Relationship between the number of leaves of main stem in spring-seeding and that in summer-seeding.

Leaf-number in spring-seeding	Leaf-number in summer-seeding: 8–10	10–12	12–14	14–16	16–18	18–20	Total number of varieties
8–10	4	15	1				20
10–12		12	4	1		1	18
12–14		3	10	3		1	17
14–16		2	11	5			18
16–18			4	8	4		16
18–20			3	13	4		20
20–22				2	10		12
22–24				2	3		5
Total number of varieties	4	32	33	34	21	2	126

r = +0.7159 (d.f. = 124), significant at the 0.1% level.

shows that leaf-number of the main stem of the respective varieties in spring-seeding is correlated with that in summer-seeding. However, the varieties with smaller leaf-number in spring-seeding had a tendency to increase the leaf-number in summer-seeding, and those with larger leaf-number in spring-seeding to decrease the leaf-number in summer-seeding.

Relationship between the reduced number of days of growth-period and the reduced number of leaves of main stem in summer-seeding compared with that in spring-seeding is shown in Table 13. This table shows the fact that reduced number of days of growth-period is correlated with the reduced number of main stem, and some of the varieties with the smaller number of the reduced days had the increased number of leaves; namely, some varieties

Table 13. Relationship between the reduced number of days of growth-period and the reduced number of leaves of main stem in summer-seeding compared with that in spring-seeding.

Reduced number of days of growth-period	Reduced number of leaves −8		−6		−4		−2		0		2		4		6		8	Total number of varieties
0																		
								5										5
10																		
		1				4		18		3								26
20																		
						1		4		12								17
30																		
				1				4		16		9		2				32
40																		
										4		3						7
50																		
										3		10		4				17
60																		
										1		4		14		3		22
70																		
Total number of varieties		1		1		5		31		39		26		20		3		126

r= +0.8120 (d.f. = 124), significant at the 0.1% level.

Table 14. Frequency-distributions of geographical variation of reduced number of leaves of main stem in summer-seeding compared with that in spring-seeding.

Districts	Latitude (N)	Reduced number of leaves −8		−6		−4		−2		0		2		4		6		8	Total number of varieties
Sweden	55–60								1										1
Denmark	55–57								1										1
Poland	50–55								1										1
Germany	47–55								1		1								2
Austria	46–49								1										1
Swit.	46–48										1								1
Hungary	46–48								2										2
U.S.S.R.	45–60						3		5		1								9
France	43–51								2										2
Rumania	43–48								1										1
Bulgaria	41–44								4		1								5
Japan																			
Aomori	40–41										1								1
Akita	39–40										1								1
Iwate	39–40										1								1
Nagano	35–37								2		3		1						6
Nara	34–35								1										1

Districts	Latitude (N)	Reduced number of leaves −8	−6	−4	−2	0	2	4	6	8	Total number of varieties
Nagasaki	32–34					4					4
Kumamoto	32–33					2	3	3			8
Kagoshima	28–32				1	13	13	14	3		44
Okinawa	24–28					2	1				3
Korea	35–43	1	1	1	2	3	1				9
China	20–50			1	4	1					6
Formosa	21–25				3	5					8
India	8–30				1	2	2				5
Philippines	5–20				1	1					2
Africa	N35–S35						1				1
Total number of varieties		1	1	5	33	44	22	17	3		126

increased the number of leaves of main stem in spite of the shortening of growth-period in summer-seeding, compared with that in spring-seeding.

Geographical variations of the reduced number of leaves in summer-seeding are shown in Table 14. Many varieties from Europe increased the number of leaves in summer-seeding. Some varieties from Korea, China and Formosa also increased the number of leaves in summer-seeding and a few varieties from Japan also increased it.

Generally, many varieties from higher latitude districts increased the number of leaves in summer-seeding when they showed the shortest growth-period. This is a tendency similar to that observed in previous paper[2].

Table 15. Relationship between the critical day-length and the reduced number of leaves of main stem.

Critical day-length	Reduced number of leaves −8	−6	−4	−2	0	2	4	6	8	Total number of varieties
13h 10m–20				1	1		3	1		6
20–30					4	7	7	2		20
30–40				2	7	6	7			22
40–50				1	6	6				13
50–14h 00			1	12	6	3	3			25
00–10			2	10	12	3				27
10–20	1	1	2	5	3	1				13
Total number of varieties	1	1	5	31	39	26	20	3		126

r= −0.6252 (d.f. = 124), significant at the 0.1% level.

As the varieties from higher latitude districts had longer critical day-length than those from lower ones, the relationship between the critical day-length and the reduced number of leaves of main stem of the varieties is shown in Table 15. What this table shows is as in the following: the critical day-length of the respective varieties is negatively correlated with the reduced number of leaves of main stem in summer-seeding, namely, many varieties having longer critical day-length increased the number of leaves in summer-seeding, and varieties having shorter critical day-length decreased the number of leaves in summer-seeding.

The above mentioned result shows that the reduced number of leaves in main stem is related both with temperature and with day-length. Relationship between the leaf-emergence interval, average number of days from the emerging of a leaf to that of next upper one, in spring-seeding and that in summer-seeding is shown in Table 16. Leaf-emergence interval in spring-seeding is correlated with that in summer-one and the interval is shortened clearly in summer-seeding, compared with that in spring-seeding.

Both the accelerating flower-bud-formation, namely, shortening of growth-period, and the increasing of leaf-number of main stem were increased by the rising of temperature in summer-seeding, compared with spring-seeding. So, the varieties having longer critical day-length showed both the shortening of the growth-period and the increasing of leaf-number of main stem under the short-day-length for them and high-temperature in summer in this district.

On the other hand, the varieties having shorter critical day-length increased the leaf-number of main stem, but could not accelerate the flower-bud-formation, namely, could not shorten the growth-period, till the day-length becoming shorter than their critical day-length in late summer. Because the day-length in early summer in this district was too long for them.

For the above reason, in the varieties having shorter critical day-length, the reduced leaf-number of main stem is correlated with the reduced number of the growth-period.

Table 16. Relationship between the leaf-emergence interval in spring-seeding and that in summer-seeding.

Leaf-emergence interval in spring-seeding (days)	Leaf-emergence interval in summer-seeding (days) 2 3 4 5 6 7					Total number of varieties
4						
		5				5
5						
		26	4			30
6						
	1	5	39	8		53
7						
			17	16	1	34
8						
		1	1	2		4
9						
Total number of varieties	1	37	61	26	1	126

r= +0.6744 (d.f. = 124), significant at the 0.1% level.

Disscussion

It is known that heading of some crops depends on photo-sensitivity, thermo-sensitivity and basic vegetative growth, namely, the shortest growth-period. Wada[10] noted that there was a high interrelation between photo-sensitivity and thermo-sensitivity of rice-varieties and their geographical distribution, namely, the varieties distributed in south western Japan showed high photo-sensitivity and low thermo-sensitivity, while the varieties in the nothern part of Japan showed low photo-sensitivity and high thermo-sensitivity. Asakuma[1] reported that the number of days from seeding to heading of the late rice-varieties was controlled by higher temperature in summer, but affected little by natural day-length when they were sown in later season. Oka[6] reported the geographical variation of photo-sensitivity and critical day-length in rice plant. Sakamoto[7] illustrated the relation between day-length and accumulated temperature from seeding to heading. The authors[2,3,4] reported the responses to day-length and temperature of Japanese standard varieties of Italian millet in relation to their seeding periods and their geographical distributions in the previous papers.

Basing on the results obtained in this experiment, the temperature and day-length in summer in this district are assumed to give the most favourable environment to shortening of the growth-period of almost all varieties of this crop, gathered from different districts, both native and foreign.

Generally, the growth-period, the sensitivity to day-length, critical day-length and the sensitivity to temperature of the varieties showed a strong relationship with their gathered districts.

The varieties from Europe showed various different characteristics in relation to the growth-period and the sensitivities of day-length and temperature, compared with those from Japan and other districts. Shorter growth-period, longer critical day-length and lower temperature for heading were the characteristics of the varieties from Europe, these characteristics of them were considered to be the result of adaptation to the climate of the districts and inferred to be some of the characteristics of German millet.

Summary

Basing on the records of the heading dates in seed-production-culture with different seeding periods for several years, the changes of growth-period of the various varieties of *Setaria italica*, gathered from different districts, both native and foreign, and their responses to day-length and temperature were discussed. The results are as follow:

1) All varieties used showed the shortest growth-period during the summer-seeding.

2) The varieties from Europe showed shorter growth-period, showing little difference of the period in different seeding dates. They had longer critical day-length and showed heading even in lower temperature.

3) The varieties from Japan showed longer growth-period and their growth-period differed greatly with the seeding dates. They had shorter critical day-length, showing heading only in higher temperature.

4) Shorter growth-period, longer critical day-length and lower temperature for heading were the characteristics of the varieties from Europe. These characteristics were inferred to be among the characteristics of German millet. And the contrary characteristics, namely longer growth-period, shorter critical day-length and higher temperature for heading, inferred to be among the characteristics of Italian millet.

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