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Effects of Day-length and Temperature upon the Flowering of Soybeans.

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Since Garner and Allard reported on the influences of day-length upon the flowering of soybeans in 1920, many investigations were carried out in this plant. Recent investigations showed that there is a relationship between day-length and temperature by which flower primordia can be initiated. As to the effect of temperature upon the flowering time in different varieties, divergent informations were made. Kobayashi (1946), Aruga (1948), Imai (1951) and Ōnishi (1951) reported that the promoting effect of high temperatures upon the flowering time of soybeans is generally higher in the summer type (early ripener) than in the autumn type (late ripener), and the intermediate type is placed between them. On the contrary, several investigators reported that under short-day condition the promotive effect of high temperature is quite similar in different varieties used (Garner and Allard (1930); Steinberg and Garner (1936); Sasamura (1950); Nagata (1950)). The author assumes that each developmental stage of the plant from germination to anthesis may have its optimum temperature and day-length.

From this point of view the present experiment was designed and conducted, in order to obtain the more precise knowledges regarding the effect of temperature and day-length upon the flowering of soybeans.

Experiment 1

Methods

The experiment was conducted in the Experimental Farm of Faculty of Agriculture, Yamagata University. Seeds were sown on the 14th of May in 1955.

The varieties used and the experimental designs were presented in Table 1.

Both categories of experiments, that is, the short-day treatments for a short period (10 days) at the different growth phases and a continuous treatment from germination to anthesis carried out in the field were included. In addition, the plots of high temperature treatment were set in the electrically controlled frame (the temperature was maintained at 20–30°C). Short-day treatments were started on the 21st of May.

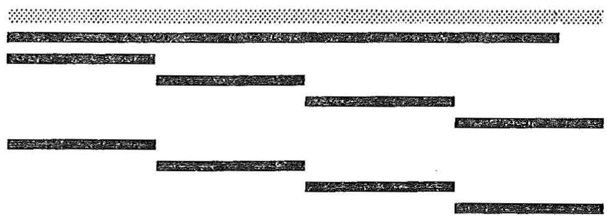
Results

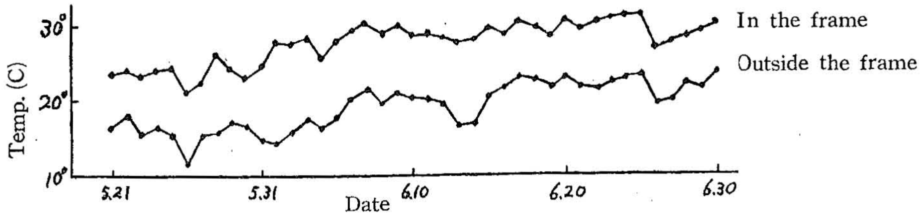
(1) On the sensitivity for short-day treatment at the different growth phases.

As represented in Fig. 1, Tables 2 and 3, there is a definite difference in number

Table 1. Experimental plots

Plot		Design	Remarks (Growth degree at the beginning of treatment)
Natural temperature	a		
	b		
	c		
	d		Primary leaf opens.
	e		2nd compound leaf appears.
	f		4th compound leaf appears.
High temperature	c′		
	d′		Primary leaf opens.
	e′		2nd compound leaf appears.
	f′		4th compound leaf appears.





Varieties used: Natural temp. plot: Shika No. 1, Ōyaji No. 1, Nakatehadaka, Ichigowase, Miyashiro, Matsuura, Nōrin No. 3, Ōu No. 13, Dekisugi No. 1, Rikuu No. 27, Shirohachikoku, Nakadeppo, Akazaya (kyoto), Tottorikurodaizu, Tamanishiki, Misaodaizu, Hankyo
High temp. plot : Ichigowase, Ōu No. 13, Tamanishiki

▬ Short-day treatment

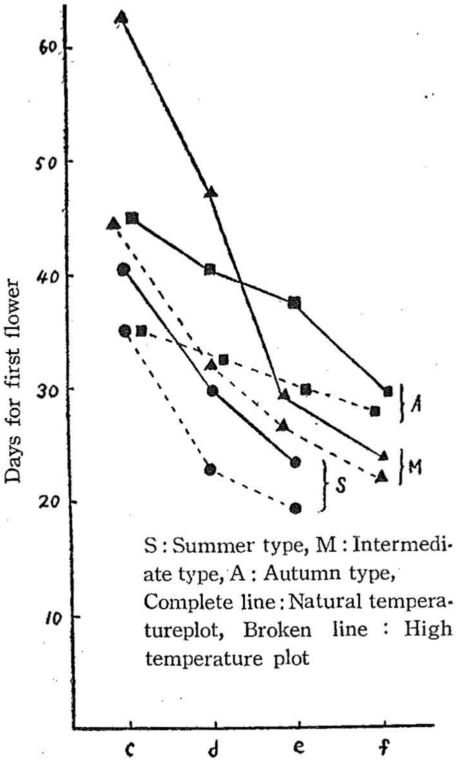


Fig 1.
Effects of the temperature upon flowering during treatments.

of days from the beginning of treatment to anthesis and in the level of the first flowering node. That is, in the plots of the continuous treatment, all varieties examined floweredt almos at the same time (about 36 days after germination), while in the plots for a short period, the later the treatment was commenced, the shorter the days from the beginning of treatment to anthesis became. In the summer type, the flowering was promoted even by the prompt treatment after germination and the promotion was greater in grade than the autumn one. In the autumn type, the circumstances were the same as in the summer type, but the degrees of the promotion were smaller than the summer one. In the intermediate type, the grade was of almost middle value between the other types, and moreover three

Table 2. Effects of short-day treatments upon flowering (1955)

Ecotypes \ Plot	Number of days from the beginning of treatment to anthesis					
	a	b	c	d	e	f
S	48.6*	35.3	41.0	30.0	24.5	
	(137.7)**	(100)	(116.1)	(85.0)	(69.4)	
M_S	56.5	35.5	44.0	33.0	29.0	23.0
	(159.2)	(100)	(124.0)	(92.7)	(81.7)	(64.8)
M_M	63.0	40.5	63.0	45.5	29.5	23.5
	(155.6)	(100)	(155.6)	(112.3)	(72.8)	(58.0)
M_A	69.3	36.0	44.3	34.7	30.0	24.7
	(192.5)	(100)	(123.0)	(96.4)	(83.3)	(68.6)
A	86.5	37.3	45.0	40.7	38.3	26.3
	(231.9)	(100)	(120.7)	(109.1)	(102.7)	(70.5)

* Average values for 10 plants.
** Comparative values of days for flowering in continuously treated plots as 100.

Table 3. Effects of short-day treatments upon the location of first flower (1955)

Ecotypes \ Plot	Location of first flower					
	a	b	c	d	e	f
S	6.1	2.4	3.8	3.7	5.0	5.8
M_S	7.1	2.2	4.5	4.0	6.0	6.9
M_M	9.0	2.3	9.0	6.6	6.0	7.0
M_A	11.1	2.1	4.7	5.2	6.5	8.6
A	18.4	2.4	4.8	7.1	9.1	9.7

Note : The rank pf flowering nodes counted from the 1st compound leaf node.

flowering types were found among them, that is, (1) the type, whose character is closely related to the summer one (M_S), (2) the type, more adjacent to the autumn one (M_A) and (3) the truly intermediate one, (M_M). But more experiments are needed for the determination of these M types, because, from the results of this experiment, this type seems to be less sensitive than the other types for 10-cycle short-day treatment in its early growing stage.

In all varieties with which continuous treatment was conducted the first flower was found at the axile of the second compound leaf, while, in the plants treated for a short period, the flower was borne at higher nodes with the delay of the beginning of treatment. In the M_M type, the short-day treatment in its early growth stage showed no distinct reaction in the promotive effect on flowering, while it reacted little in the treatment of 10 day cycles after germination.

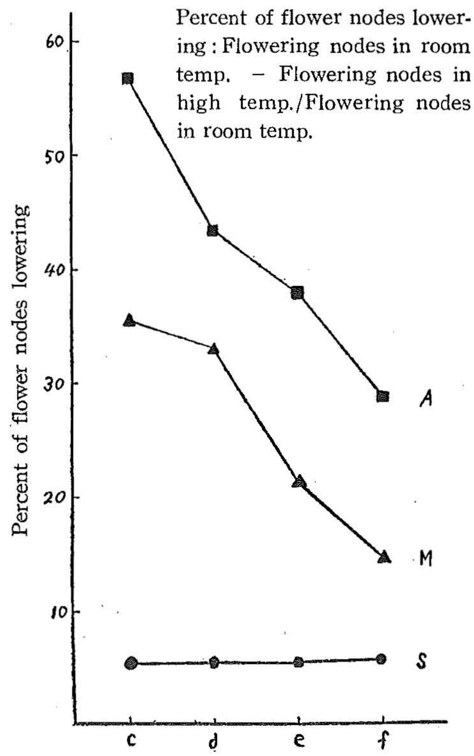


Fig 2.
Effects of the temperature upon location of first flower nodes.

(2) **The effect of temperature on the short-day treatment for a short period.**

The data obtained are given in Figs. 1 and 2.

In the autumn and intermediate types, the flowering was promoted by the high temperature (20–30°C) given at the early stage of the growth, but this effect was decreased when it was given at the later stage. On the other hand, in the summer type, the flowering was promoted by the high temperature treatment given at any stage.

Experiment 2

Methods

This experiment was carried out from May to August, 1956, in the Experimental Farm, Faculty of Agriculture, Kyoto University. It was conducted in the same manner as in 1955, but without the high temperature plot. Varieties used were Ichigowase (early ripener), Ōu No. 13 (mid ripener), and Tamanishiki (late ripener), and they are all typical ones in each ecotype. Seeds were sown on 14th of May.

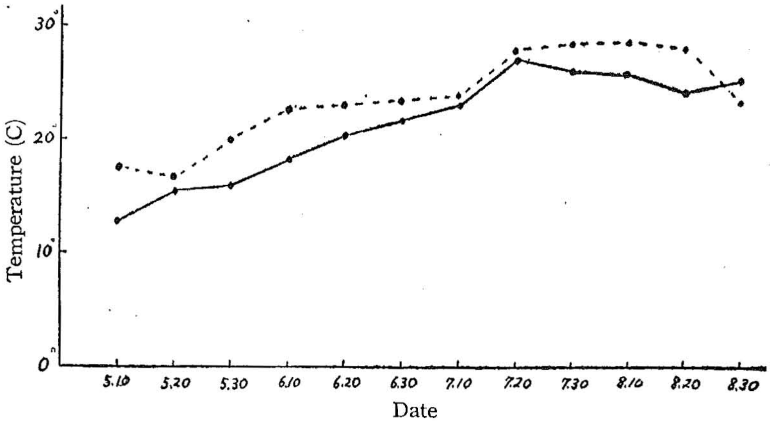


Fig. 3. Variation of the temperature during the growing period in two localities.
Complete line : Yamagata (1955), Broken line : kyoto (1956)

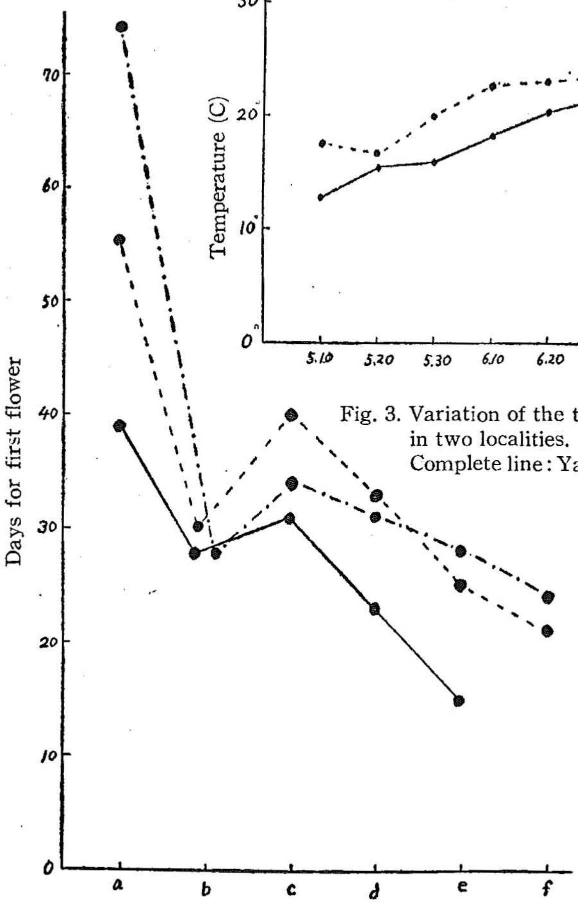


Fig. 4. Varietal differences for short-day responses.
Complete line : Ichigowase, Broken line : Ōu No. 13, Chain line : Tamanishiki

Results

As represented in Fig. 4, although in each treatment the number of days from the beginning of treatment to anthesis is shortened in comparison with the results in Experiment I, the tendency being similar.

Experiment 3

Method

This experiment was conducted from September 1956 to January 1957 in the Experimental Farm and the Phytotron attached to the Faculty of Agriculture, Kyoto University. The experimental design was shown in Table 4.

Table 4. Experimental plots (1956)

Plot	Sowing time	Temp. (C)	Remarks	Place
Const. temp., natural day-length (A)	9.1	20°	Day-length…… 9.7th :	Phytotron
Const. temp., natural day-length (B)	9.1	30°	13.43 hrs, 9.17th : 13.21 hrs	Phytotron
Const. temp., natural day-length (A′)	9.20	20°	Day-length……9.27th :	Phytotron
Const. temp., natural day-length (B′)	9.20	30°	13.00 hrs, 10.7th : 12.38 hrs	Phytotron
Const. temp., continuous illumination (C)	9.1	20°		Phytotron
Const. temp., continuous illumination (D)	9.1	30°		Phytotron
Alternating temp., natural day-length (E)	9.20	30°→20°*		Phytotron
Alternating temp., natural day-length (F)	9.20	20°→30°**		Phytotron
Controle (G)	9.1			Farm
Continuous short-day treat. from germ. to the anthesis (H)	9.1			Farm
Short period treat. after germ. (I)	9.1			Farm

* From 8.00 A.M. to 5.00 P.M. : 30°C, From 5.00 P.M. to 8.00 A.M. : 20°C
** From 8.00 A.M. to 5.00 P.M. : 20°C, From 5.00 P.M. to 8.00 A.M. : 30°C

Supplementary light for continuous illumination was obtained with the use of 100 W Mazda filament lamp suspended about one meter over the plants. The experimental plants in the phytotron were grown in the 5-inch pots.

Results

(1) The effect of temperature under natural-day length

The result was given in Tables 5 and 7.

Flowering was more promoted in 30°C plot than in 20°C plot, including both plots planted on Sept. 1st and on the 20th of the same month. In general, in both summer and autumn types, the flowering was more accelerated as compared with

Tadle 5. Effects of day-length and temperature upon the flowering (1956)

I Sown Sept. 1

Plot \ Variety	Ichigowase		Ōu No. 13		Tamanishiki	
	Days for 1st flower	1st flower node	Days for 1st flower	1st flower node	Days for 1st flower	1st flower node
A	38.0	6.0	43.0	6.0	41.5	5.5
C	86.0	15.0	104.0*	15.0		
B	23.0	5.5	26.0	6.0	25.0	5.5
D						
G	32.0	4.6	41.0	5.4	32.0	4.0
H	31.0	4.0	33.5	5.0	28.0	4.0
I	31.0	4.5	41.0	5.8	30.0	4.0

II Sown Sept. 20

Plot \ Variety	Ichigowase		Ōu No. 13		Tamanishiki	
	Days for 1st flower	1st flower node	Days for 1st flower	1st flower node	Days for 1st flower	1st flower node
A′	37.5	5.0	37.5	6.0	36.5	5.5
B′	26.0	6.0	31.0	6.0	28.5	6.5
E	26.5	6.0	32.0	6.0	27.0	5.5
F	29.5	6.0	36.0	7.0	33.0	6.0

* Cleistogamous flower

Table 6. Effects of temperature upon flowering after photo-induction (1956)

Plot	Days for 1st flower	1st flower node
After 4 cycles photo-induction (at 20°C) placed under continuous illumination (at 20°C)	*57.5	8.0
After 4 cycles photo-induction (at 20°C) placed under continuous illumination (at 30°C)	**	
After 4 cycles photo-induction (at 30°C) placed under continuous illumination (at 20°C)	*57.0	8.0
After 4 cycles photo-induction (at 30°C) placed under continuous illumination (at 30°C)	**	

* Cleistogamous flower, ** Flower buds were borne, but not flowered.

Table 7. Effects of day-length and temperature upon flowering (1956)

Variety	Sown on Sept. 1 (Ⅰ)			Sown on Sept. 20 (Ⅱ)			Ⅰ-Ⅱ/Ⅰ (%)	
	20 (L)	30 (H)	L-H/L(%)	20 (L)	30 (H)	L-H/L(%)	20°	30°
Ichigowase	38.0	23.0	39.5	37.0	26.0	29.7	+ 2.6	− 13.0
Ōu No. 13	43.0	26.0	39.5	37.5	31.0	17.3	+ 12.8	− 19.2
Tamanishiki	41.5	25.0	39.8	36.5	28.5	21.9	+ 15.7	− 14.0

Note : L-H/L (%) ……Means of the percentage of hastened flowering due to high temperature.
Ⅰ-Ⅱ/Ⅰ (%)……Means of the percentage of delayed or promoted flowering caused by different sowing time.

the intermediate type. In 20°C plot, the periods required from germination to anthesis were shorter in the plots planted on September 20th than in the plots planted on the lst of the month. On the contrary, in the 30°C plot longer periods were required in the later sown plot, though the natural day-length became shorter.

In the alternate temperature plot (from 30°C day temperature to 20°C night temperature and from 20°C day temperature to 30°C night temperature), all varieties flowered earlier in the plots in which the temperature was higher in the daytime than in the night.

(2) The effect of temperature under continuous illumination

The results were represented in Table 5. In 20°C plot Ichigowase flowered 86 days after planting, Ōu No. 13 bore cleistogamous flowers 104 days after planting, and Tamanishiki did not bear any flower until the termination of this experiment, but no varieties flowered in 30°C plot. In Tamanishiki, when the treated plants were placed at 20°C and 30°C respectively after receiving the photo-induction of 4-cycles at 20°C and 30°C, all plants placed at 20°C initiated flower primordia, and then bore cleistogamous flowers, but those placed at 30°C initiated no flower primordia. (cf. Table. 6).

Discussion

All varieties of each ecological type showed progressively higher responses to the photo-induction treatments as they grew older, and striking differences of the period at which the responses became great were found among those varieties, until the termination of this experiment.

Borthwick and Parker (1939) reported that the initiation of flower primordia was seen in many early varieties under continuous illumination and therefore darkness is not indispensable for floral initiation, but the reaction was more accelerated by short-day treatment as in late varieties. Early and late varieties are not fundamentally different concerning the floral induction, but their relative ages at which the similar reactions were recognized by short-day treatment are strikingly different.

If we assume the age of the most sensitive reaction as that at which the plant ripes to flower, early varieties seem to reach this age faster than late ones, when these plants are grown under the same condition. From these points the results given in Table 2 are very interesting. The days from the commencement of the treatment to anthesis were most shortened in the summer type, as compared with those under continuous treatment ; then the intermediate type followed and the autumn one the last. Although M_S and M_A types among intermediate type (M), show similarly the considerable response in early age, the reaction increases more rapidly in M_S type than M_A type ; consequently it is analogous to S type. On the other hand, M_A type responses more slowly, so that it is analogous to A type.

It has been already shown that early varieties flowered under continuous illumination. In this experiment too the early variety flowered, and moreover the intermediate type bore cleistogamous flowers. Tamanishiki, an autumn type, did not flower, but flower buds were initiated. Therefore it may be said that soybeans are used to flower even if they are exposed to unfavourable condition just as continuous illumination. However, no varieties flowered at 30°C under the same condition. This result explains that the high temperature as 30°C may have an inhibiting effect upon flowering at the later stage of flower development. The experiments in which the sowing time varied resulted in that the high temperature plot (30°C) retarded them to flower even under natural short-day condition as sown on September 20. But the mechanism concerning this phenomena is not clear. It is shown from these results that there may be optimum temperature in each growth phase from floral induction to anthesis as well as optimum day-length for flowering. This is clarified by the data shown in Table 5.

According to the past investigations, it is reported that the effect of short-day treatment appears only after the emergence of primary leaf, and the same effect does not appear promptly after germination. But the results of the present experiment showed that the response to this effect was found in the cotyledonous stage. It is supposed that it is due to different varieties, duration of the treatment and temperature during the treatment.

In regard to the node on which the first flower appeared, all varieties used bore them similarly on 2.0~2.5th nodes. The prompt treatments after germination lowered considerably the flower bearing nodes as compared with the controls. Therefore these results suggest that cotyledons may also respond to the effect as is shown in the results of flowering dates.

The growth of soybeans is used to be promoted and the days from germination to anthesis are shortened when optimum temperature is given. In this case, it is considered that the temperatures will be closely related to day-length for flowering. To clarify this point, more exact observations and experiments will be needed.

Summary

These experiments were designed and conducted in order to clarify more precisely the various responses of soybeans to day-length and temperature. In 1955, the short-day treatments for a short period (10 days) at the different growth phase and a continuous treatment from germination to anthesis were carried out with 17 varieties of soybeans including 5 ecotypes in Faculty of Agriculture, Yamagata University. In 1956 3 varieties, typical varieties of 3 ecotypes were used, and the relationship between day-length and temperature was investigated more in detail in Faculty of Agriculture, Kyoto University.

The results obtained are summarized as follows :

1) In the plots of the continuous treatment, all varieties (examined flowered almost at the same time (about 36 days after germination), while in the plots for a short period, the later the treatment was commenced, the shorter the days from the beginning to the anthesis became. That is, the effectiveness of a photoperiodic treatment increased with the age of plants treated. In comparison with the late variety (autumn type), the early variety (summer type) responded to the treatment at the earlier stage of growth.

2) In all varieties treated continuously, the first flower was borne at the axile of the second compound leaf, while, in the plants treated for a short period, the flowers were found at higher nodes, successively with the delay of the time of treatment.

3) In the late and intermediate varieties, the flowering was promoted by the high tempereture (20~30°C) given at the early stage of the growth, but this effect was decreased when given at the later stage. On the other hand, in the early variety the flowering was promoted by high temperature treatment given at any stage.

4) It is expected that there is optimum temperature in each phase from floral induction to anthesis as well as optimum day-length.

5) The plant even under unfavourable condition seems to reach the differentiation of flower bud and flowering stage ultimately when it grows older.

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摘　　要

大豆の開花に及ぼす温度及び日長の影響

竹　島　溥　二

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本実験は大豆の開花に及ぼす温度及び日長の影響を明らかにする目的で1955年及び1956年の２年に亙り行なわれた．

1955年は山形大学農学部の圃場で５種の生態型に属する17品種の大豆を供試して，各生育時期別に短期間の短日処理及び発芽直後より開花期までの長期間の短日処理を行ない，これが開花に及ぼす影響の差異を調査した．1956年は京都大学農学部の圃場及び制御温室で３種の生態型に属する代表的３品種を供試し，開花に及ぼす温度及び日長の関係をさらに詳しく調査した．

その結果を要約すれば次の如くである．

1．長期処理では到花日数はほぼ一定しているが，短期処理では処理の時期がおくれるに従つて，その到花日数が短かくなる．そして異なる生育時期における短日感応性の差異は著しく，いずれの生態型の品種においても生育が進むとともに感受性が増加するが，感受性の高まる時期は夏大豆型は早く，秋大豆型は晩い．

2．開花節位は長期処理では，ほぼ一定しており第２節附近にあるが短期処理においては処理時期のおくれるに従い概して上昇の傾向がある．

3．短期処理の効果に及ぼす温度の影響は，秋大豆型と中間型において高温は短期の短日処理の場合著しい促進効果をもたらすが，後期では差が少なくなる．これに反して夏大豆型では高温は常に促進的にはたらき時期的な差はほとんどない．

4．開花に対し適当な日長があるように，温度にも適温があり，また温度と日長との間には密接な関係があるもののようである．

5．生育の経過とともに花熟状態への転換が起り，その結果普通には開花し得ないような環境の下でも開花するに至るようになるものと考えられる．