Studies on the Reproductive Growth of the Mulberry

1. On the Period of the Floral Formation and the Photoperiodism

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I. Introduction

In general, the mulberry seldom has a floral induction, unless it elapses several years after sowing or planting. This fact is inconvenient in the breeding of mulberry, and, therefore, it comes into question to accelerate the floral induction.

Although it is considered that determination of a period of floral initiation is a fundamental matter in the acceleration of the floral induction, reports concerning to it, so far as the authors know, have scarcely been published, and the settlement of this question has been remained insufficiently up to date.

At first the authors engaged in the research of the period of floral formation and in the next investigated on the effect of photoperiodic treatment on the reproductive and vegetative growth together with the defoliation.

II. Experimental results and Discussion

1. Researches of the period of the floral formation

Experiment I—1 (in 1954)

The material was taken from Hino mulberry field belonging to the Sericultural Experimental Station at Tokyo.

Eleven forms which are apt to have flower buds, were used and the collection of these materials was begun on the 25th of May. Investigation was carried out about the three kinds of material differing in their cultural method, i.e. *Harugari* (spring-cutting), *Natsugari* (summer-cutting), and *Tatedōshi* (non-cutting).

Two wattles were selected as the experimental material and from these materials, except for 3～4 buds of the base of the wattle, the next upper 5 buds (together with 10 buds) were taken off, and these buds were preserved in 70 % alcohol for the investigation of the floral primordia at suitable time. But only in the case of the form "Murasakiwase" of *Tatedōshi*, 5 buds were removed immediately from the base of the new shoot.

In the investigation of floral primordia in these buds the authors used *Hakuhi* method which strips off the bud scales and makes the inner part of buds observable solidly under a dissecting microscope.

As shown in Table 1, the period of the floral formation of the new shoot was about the beginning of June in the form "Murasakiwase" of *Tatedōshi* and in the case of *Harugari* that of each form except for the form "Shiromekeisō" was about from mid to late June. Also the floral primordia in the *Natsugari* was

Table 1. Researches on the period of the floral formation*

Form	Sex of the material	Year-old after plantation	Strain	Spring, or summer cutting; and its date	Date of the collection of buds and existence of floral primordia									
					May	June			July				Aug.	Sept.
					25th	4	14	28	5	12	19	26	2	15
Shinsō-No. 1	♀	14	*Morus bombycis* Koidz.	Summer (VI. 7)	—**	—	—	—	—	○	—	○	—	○
Shinsō-No. 2	♀	14	〃	〃 (〃)	—	—	—	—	—	○	—	○	—	○
Yaechijira	♂	14	〃	〃 (〃)	—	—	—	—	—	○	—	○	—	○
Shimanouchi	♂	14	〃	〃 (VI. 30)	—	—	—	—	—	×	—	×	—	×
Risō	♀♂	24	*Morus alba* Linn.	〃 (V. 29)	—	—	—	—	○	○	○	○	○	○
Shiromekeisō	♂♀	16	〃	〃 (〃)	—	—	—	—	×	×	×	△	○	○
Ohatawase-zyūmonji	♂	14	〃	〃 (VI. 7)	—	—	—	—	—	○	—	○	—	○
Jinsō	♀	14	*Morus latifolia* Poilet	〃 (〃)	—	—	—	—	—	○	—	○	—	○
Shimanouchi	♂	24	*Morus bombycis* Koidz.	Spring (IV. 10)	×	×	×	○	○	○	○	○	○	○
Kenmochi	♀	2	〃	〃 (〃)	×	×	△	○	○	○	○	○	○	○
Shiromekeisō	♀♂	16	*Morus alba* Linn.	〃 (〃)	×	×	×	×	×	×	○	○	○	○
Kokusō-No 70	(♀♂)	16	*Morus latifolia* Poilet	〃 (〃)	×	×	△	○	○	○	○	○	○	○
Murasakiwase	♀(♀♂)	44	*Morus bombycis* Koidz.	Non-cutting (—)	×	△	○	○	○	○	○	○	○	○

*: Materials were taken from Hino mulberry field belonging to the Sericultural Experimental Station, Tokyo, in 1954.

** ○: Buds which had floral primordia.

△: Buds which had something resembling to floral primordia.

×: Buds which had no floral primordium.

—: Observations were omitted.

observed surely one month after *Natsugari* procedure (wattle length: 20 ~ 30 cm, the number of unfoled leaves: 7 ~ 8).

Any reports with respect to the period of floral formation in mulberry have been scarcely published except for the Suzuki's[1] report which investigated chiefly the development of floral primordia. He described that the floral induction was in the beginning of June in the case of the form "Enshūtakasuke" of *Tatedōshi*. His report agrees with the result obtained in the present observation by the form "Murasakiwase" of *Tatedōshi*.

Experiment I—2 (in 1955)

The material was taken from mulberry field attached to the Faculty of Agriculture, Kagoshima University. Ten forms that generally have been cultured in Japan, were used. The period of floral formation was investigated in the cases of both *Harugari* and *Natsugari*. Not only an old mulberry but also a young one which does not still arrive at flowering age, were chosen as the object of the investigation. The method taking off the buds was used as in the first experiment.

The results obtained are shown in Table 2. The floral primordium in the axillary bud of the new shoot was observed in late May in the case of the form "Ōshima" (30-year-old after planting) of *Harugari* while in the case of the form "Kairyōwasezyūmonji" (30-year-old after planting) it appeared in mid July. However, in the case of the form "Shūkakuichi" (30-year-old after planting) of *Natsugari*, the floral formation was induced in mid July, namely about 2 months after the procedure of *Natsugari*, while as to the form "Ōshima" it appeared in mid August, namely about 3 months after the procedure of *Natsugari*. Young trees generally were difficult to have floral primordia, but only the trees of form "Enshūtakasuke" (4-year-old after planting) produced them.

Slowness or quickness of the floral formation seems to be controlled by the characteristics of the form and the number of years after planting or sowing. So there were some differences in the period of floral formation even among the forms cutted in the same season, for example, the spring-cutted "Ōshima" induced the sufficient floral primordia in the axillary bud of the new shoot in late May, while the forms "Kairyōwasezyūmonji" and "Siromekeisō" showed them far later. The same phenomenon was observed in *Natsugari* as well as in *Harugari*, i.e as to the forms such as "Shinsō-No. 1," "Yaechijira," "Rosō," "Ōhatawasezyūmonji," and "Jinsō," the floral primordia appeared early (about one month after the procedure of *Natsugari*), while as to the forms such as "Shiromekeisō" and "Shūkakuich," their appearance was late (2 months or more after the cutting). The time of cutting also influenced upon the formation of floral primordia.

The "Ōshima" which was cutted on the 2nd of July induced floral primordia far later than the tree of the other forms cutted in May, and the "Shimanouchi" which was cutted on the last day of June did not showed the primordium. These must be attributable to the lateness of cutting, and consequently, also to the badness of the growth of the shoot.

At any rate, the period of the floral formation seems to be fairly early, i.e. in a little while after the flowering and fruiting of that year the floral primordia of the next year was induced in axillary buds of the new shoot.

Table 2. Researches on the period of the floral formation*

Form	Year-old after plantation	Strain	Spring, or summer cutting and its date		Date of the collection of buds and existence of floral primordia										
					May		June			July			August		
					14th	25	5	15	25	5	15	25	5	15	25
Ōshima	30	*Morus latifolia* Poilet	Spring	(III. 7)	—**	○	○	○	○	○	○	○	○	○	○
Kairvōwasezyūmonji	30	*Morus alba* Linn	〃	(〃)	×	×	×	×	×	×	○	○	○	○	○
Rosō	2	*Morus latifolia* Poilet	〃	(〃)	×	×	×	×	×	×	×	×	×	×	×
Shūkakuichi	30	*Morus alba* Linn.	Summer	(V. 13)	—	—	—	—	×	×	○	○	○	○	○
Ōshima	30	*Morus latifolia* Poilet	〃	(VII. 2)	—	—	—	—	×	×	×	×	×	○	○
Enshūtakasuke	4	*Morus bombycis* Koidz.	〃	(V. 25)	—	—	—	—	×	×	—	○	○	○	○
Shūkakuichi	4	*Morus alba* Linn.	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×
Rosō	4	*Morus latifolia* Poilet	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×
Kairyōnezumigaeshi	4	*Morus alba* Linn.	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×
Ichinose	4	〃	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×
Kokusō-No. 21	4	*Morus latifolia* Poilet	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×
Kokusō-No. 27	4	*Morus alba* Linn.	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×
Tomiesō	4	〃	〃	(〃)	—	—	—	—	×	×	×	×	×	×	×

*: Materials were taken from mulberry field of the Faculty of Agricultur, Kagoshima University, in 1955.

** ○: Buds which had floral primordia.

×: Buds which had no floral primordium.

—: Observations were omitted.

Sometimes, however, flowers appear in spring only on the apical part of the wattle which elongated in autumn. As the main object of this experiment was to research the period of the floral formation from spring to summer, it has no concern with autumn.

2. Effect of the photoperiodic treatment on the number of floral buds

Experiment II—1 (in 1954~1956)

The grafted sapling of the forms "Rosō," "Okinawa" and a seedling-A (the form of which is obscure and which has passed the second year after sowing) were planted in boxes (30 × 30 × 40 cm.). Each box contained one sapling, from which all buds were taken off except the two which were allowed to elongate.

Of these materials neither cutting of shoot nor picking of leaves during the experiment was done. Concerning the photoperiodic treatment three lots were situated, namely natural day length, short (8 hour day length from 9:00 to 17:00) and long (continuous illumination by two 100 W-Matsuda-lamps) photoperiods.

Each set of material in the experiment was consisted of two boxes of sapling of the same form, respectively "Rosō," "Okinawa" or the unknown seedling-A. The photoperiodic treatment was started on the 24th of March in 1954.

The mixed-manure was applied to each box in proper quantity on the 4th of May and the 1st of July. Water was supplied to the materials in response to the requirement. When the typhoon approached, the sets under the natural and long photoperiod were brought into a room in order to protect against the damage, while the set under the short photoperiod could be continued short photoperiodic treatment by using of the dark room. By the attack of the Typhoon No. 22 on the 28th of September, 1955, the photoperiodic procedures became impossible and henceforth each set was changed into natural day-length.

The results of the investigation on the floral buds in 1955 and 1956, the first and second years after the beginning of photoperiodic procedure, respectively, are shown in Table 3.

Table 3. Effect of photoperiodic treatment* on the number of floral buds

Sort of Sapling	Form	Photo-periodic tretment	Number of floral buds			
			Autumn, 1954	Spring, 1955	Autumn, 1955	Spring, 1956
Grafting	Rosō	Natural-day	0	♀ 1	0	♀ 660
		Short-day	0	♀ 11	0	♀ 308
		Long-day	0	♀ 1	0	♀ 115
	Okinawa	Natural-day	0	♀ 9	♀ 123	0**
		Short-day	0	♀ 17	♀ 212	♀ 5
		Long-day	♀ 1	♀ 16	♀ 198	♀ 53
Seedling-A	Obscure	Natural-day	0	0	0	♀ 315
		Short-day	0	♂ 235	0	♂+♀ 613
		Long-day	0	0	0	♀ 83

*: The photoperiodic treatment was started on the 24th of March in 1954.
**: A symptom of dwarf disease was observed in spring of 1956.

As to the form "Rosō" the floral buds were observed in spring of 1955 (the second year after the planting). Number of the floral buds of the wattle grown under the short photoperiod was 11; the number was larger than those of two other photoperiodic lots.

From this fact, it seems to be obvious that the floral formation of form "Rosō" in the second year after the planting is accelerated by exposure to short photoperiod during the previous year. However, it can not be said that number of the floral buds of the wattle in the third year after the planting which had been grown under the continuous short photoperiodic treatment during two years was more in comparison with those of two other photoperiodic lots.

In general, it has been known that in the form "Okinawa" belonging to race "Shimaguwa" the floral buds are induced mainly two times, in spring and autumn. In the present experiment, no difference in the number of floral buds could be seen among lots.

Also in the set of seedling-A (the form of which was obscure but presumably resembled "Rosō" rather than "Shimaguwa") the number of the floral buds was maximum in 1955 as well as in 1956 (namely the 3rd and 4th year after the sowing) in the wattle grown under the short photoperiod.

From the results obtained in those experiments it was recognized that the short photoperiodic conditions were effective to promoting the floral induction of grafted "Rosō" wattles and the seedling-A, at least in the early stages after planting or sowing.

However, it could not be said that with the progression of tree age the short photoperiodic conditions were always promotive to the floral formation, and consequently, the conspicuous difference in the number of floral buds was not seen among lots. The effect of the photoperiodic treatment on the reproductive growth seemed to become slighter with the age after the sowing or planting.

The long photoperiodic conditions seemed to be inconvenient for the floral formation of the form "Rosō," while for the form "Okinawa" the same conditions were not so bad compared with short or natural photoperiod, rather somewhat better than the last mentioned condition.

The less number of buds of the "Okinawa" wattle grown under the natural photoperiod may be attributable to the fact that this material was attacked by a dwarf disease in spring of 1956 which corresponded to the end of these experiment.

At any rate, the sensitivity of the flowering responses to photoperiod was not so clear in the form "Okinawa."

In general, it has been said up to the present time that the mulberry seems to be a long-day plant to some extent. From present experiment, however, it is assumed that in the form such as "Rosō," at least, the procedure of short photoperiod acted in the early stage of the material accelerates the floral formation and such a form may be called a slight short-day plant.

Reports of experiments on the flowering responses of other woody plant to photoperiodic conditions are very few in number.[2][3][4][5][6] There are a few reports of the effective daylength condition on the floral initiation in some woody plants.[2][7][8] On the other hand, photoperiodic treatment apparently has little effect on floral initiation in azalea[9][10] and apple[11][12] and in the gardenia are somewhat conflincting.[13][14][15]

The effect of photoperiodic treatment on the floral formation of mulberry does not seem so clear as in some plants, even though it appears to be a slight short-day plant from present experiment.

In spring of 1955, male flowers only were induced in the wattle of the short-day lot, but in the next spring female flowers also mixed with them. This fact is noticeable matter as regards to the connection between a sexual character of the mulberry and photoperiodism.

Experiment II—2 (in 1955 ~ 1956)

The seeds immersed in water for 5 hours so as to absorb enough water were put on suitably wet filter paper in a Petri dish which was placed in an incubator of 30° C. After about 4 to 5 days the seeds sprouted to a length of 10 to 20 mm.

A lot of materials selected was vernalized for 30 days in a low temperature of 5° C (in a dark refrigerator). Another lot was planted in pots as the control immediatly after the sprouting and without subjecting to the low temperature. These pots of both vernalized and non-vernalized materials were exposed to the three different photoperiods: natural, short and long photoperiods. They were suitably supplied with water but were not with manure.

The results are shown in Table 4. The growth and development of the vernalized plants were not so good and fairly many withered individuals were seen.

When the winter buds sprouted in spring of 1956, the number of floral buds was investigated. Every material of each photoperiodic lot in both the vernalized and non-vernalized, did not bring about a floral formation.

Table 4. Effect of the photoperiodic treatment following the vernalization, on the flowering*

Form	Date of planting	Duration of vernalization (days)	Number of flowering (Number of individuals observed in parentheses)		
			Natural-day	Short-day	Long-day
Ichinose	VII. 7	30	0 (24)	—	0 (3)
	〃	0	0 (24)	0 (5)	0 (1)
Kairyōwase-zyūmonji	VII. 7	30	0 (5)	—	0 (6)
	〃	0	0 (18)	—	0 (1)
Rosō	VII. 7	30	0 (6)	—	0 (5)
	〃	0	0 (16)	—	0 (5)
Ōshima	VII. 7	30	0 (8)	—	0 (5)
	〃	0	0 (42)	0 (4)	0 (21)
Shūkakuichi	VI. 11	30	0 (6)	—	0 (12)
	〃	0	0 (43)	0 (16)	0 (12)
Okinawa	VI. 21	30	0 (15)	—	0 (1)
	VI. 6	0	0 (30)	0 (15)	0 (12)

*: Date of observationn was the 29th of March, 1956.

3. Effect of the photoperiodic treatment on the vegetative growth

Experiment III—1 (in 1953)

Materials were taken from the mulberry field attached to the Faculty of Agriculture, Kagoshima University.

The forms "Rosō" and "Ichinose" of *Harugari* (3-year-old after planting), and of the same size, were dug out in March and each mulberry stump was planted in a box (30 × 30 × 40 cm). The number of shooting wattles was limited to four in each mulberry stump. 15 individuals were tested for one experiment.

These materials were exposed to three different photoperiodic conditions i.e. natural, short (8 hours: 9:00 ~ 17:00) and long (16 hours: supplementarily illuminated with two 100 W-Matsuda-lamps from 17:00 to 22:00) photoperiods.

The sets of each treatment had 5 individuals of testing materials. A mixed-manure was given only one time before the experiments. The measurement was done at 5 day intervals.

These experiments were carried out in the following two seasons according to the period exposed to the photoperiod.

i) In summer (From the 25th of July to the 30th of August)

ii) In autumn (From the 15th of October to the 25th of November)

Each photoperiodic procedure was started at the same time of the onset of the experiments; and the growth rates shown in Fig. 1 were measured on the last days dated above respectively.

Comparing the mean extention growth per individual, the followings are known: the extention growth of the wattle in the long-day lot was the largest, and in the natural-day lot the second and in the short-day lot the least.

This fact agrees with the results of Hotta[16] and Taguchi[17] using mulberry. The effect of daylength upon extention growth has been investigated with several woody plants by many workers. The reduction in total growth under short photoperiodic conditions is often very striking, so that, for example, first year seedlings of *Robinia pseudacacia* and *Larix sibirica* attain a maximum height of only 3 to 5 cm if maintained under short photoperiodic conditions from germination.[18]

The extention growth of the form "Rosō" was always better than that of "Ichinose" except the case of natural-day lot in autumn experiment.

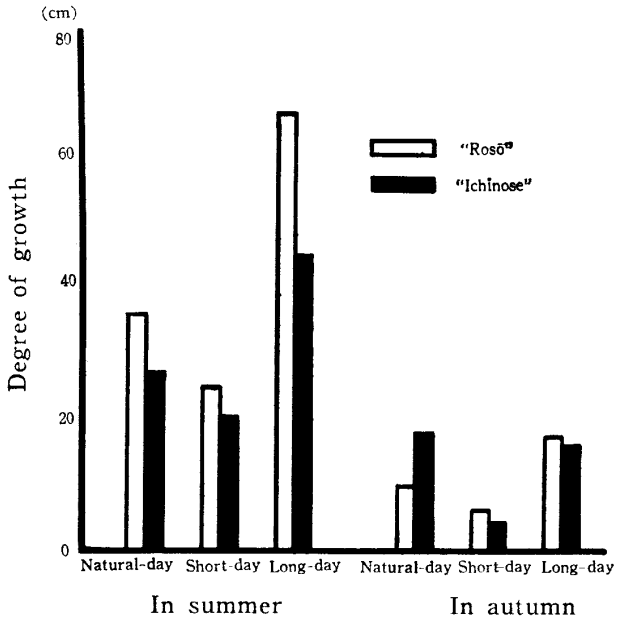

Fig. 1. Effect of photoperiodic treatment on the extention growth.

Experiment III—2 (in 1954)

The extention growth of every wattle in each lot was measured at intervals of a week employing the material used in Exp. I—1.

Summary of this experiment is shown in Table 5. Of the mean length of wattles the largest was seen in the wattle of long-day lot, next to that came the natural-day lot and the short-day lot the smallest.

Concerning the mean number of attached leaves the natural-day lot showed the largest value, the short-day lot the next and the long-day lot the least.

Although the number of attached leaves in long-day lot of "Rosō" was fewer than that of two other photoperiodic lots, the wattle length of that lot showed the largest value. This fact may be attributable to the difference of the length of the internodes (in long-day lot: 4.0 cm, in natural-day lot: 3.0 cm, in short-day lot: 3.1 cm). Moreover, the apical portion of every wattle exposed to the long photoperiod has begun to hang down and bent on about the 10th of August.

It is noticeable that the periods of stoppage of growth in the three lots nearly agreed in one time, namely, mid or late of September. This period of stopping of growth was earlier than that of ordinary case where the leaves were removed in summer or in the beginning of autumn. This earliness of stopping of growth may be partially due to the presence of leaves which were not picked away in summer or autumn.

The largeness in extention growth of the long-day lot was not the result of continuance of growth until late, but was due to a vigorous growth during the

Table 5. Effect of photoperiodic treatment on the vegetative growth

Form	Photo-periodic treatment	Mean length of wattles (cm.)	Mean number of attached leaves	Mean length of internodes (cm.)	Period of stopping of growth
Rosō	Natural-day	173 (100)*	58 (100)	3.0	Middle~late of Sept.
	Short-day	164 (95)	53 (91)	4.1	〃
	Long-day	194 (112)	48 (83)	4.0	〃
Okinawa	Natural-day	94 (100)	29 (100)	3.2	Early~middle of Aug.
	Short-day	146 (115)	41 (141)	3.6	Late sept.~early Nov.
	Long-day	156 (166)	38 (131)	4.1	Middle~late of Sept.
Seedling-A**	Natural-day	78 (100)	28 (100)	—	—
	Short-day	65 (83)	41 (146)	—	—
	Long-day	116 (149)	51 (182)	—	—

*: The value of natural-day was regarded as 100, respectively.
**: Form of the material obscure.

Table 6. Effect of the photoperiodic treatment on the shooting of lateral branches

Form	Photoperiodic treatment	Mean number of attached leaves (A)	Mean number of lateral branches (B)	$\frac{(B)}{(A)} \times 100$
Okinawa	Natural-day	29 (100)*	12	41 (100)
	Short-day	41 (141)	5	12 (29)
	Long-day	38 (131)	14	37 (90)
Seedling-A**	Natural-day	28 (100)	17	61 (100)
	Short-day	41 (146)	10	24 (39)
	Long-day	51 (182)	21	41 (67)

*: The value of natural-day was regarded as 100, respectively.
**: Form of the material was obscure.

growing period. These facts can be seen in Figs. 2 and 3 which showed a weekly rate of growth (denoted in a mean per day).

It has been indicated that photoperiodic conditions have little or no effect on the duration of extention growth in various varieties of apple.[11][12]

On the other hand, in the form "Okinawa" the sprouting of the axillary buds and defoliation take place several times in a year, and usually lateral branches are produced in the very year of plantation, and thus a frutex (shrub)-like plant is formed. Such phenomena are scarcely seen in the mulberry including "Rosō" and its allies which are cultivated generally in Japan. Consequently, the measurement of the extention growth was very complicated. Table 5 shows the mean length of the growth and the period of stopping of growth of the two shoots sprouted at onset of the experiment. To discuss the growth rate it must be also taken into consideration the number of the lateral branches as shown in Table 6. The maximum length of the wattles was seen in the long-day lot, and the second was in the short-day lot, while the smallest was in the natural-day lot. The fact that the extention growth of the wattle under short photoperiod was larger than that of the natural-day suggests that the sprouting of the lateral branches was less in short-day lot than that in natural-day. And the form "Okinawa" seems to be fairly sensitive to the temperature, thus, the fact that the temperature of the dark room in which short photoperiodic

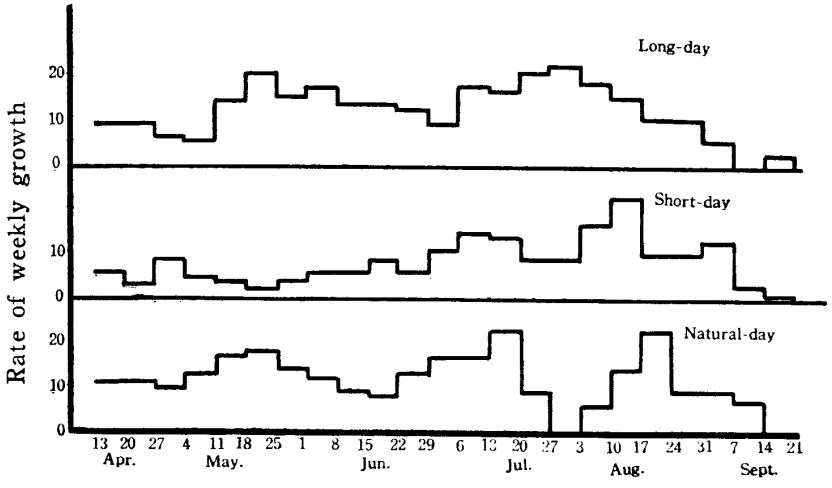

Fig. 2. Effect of photoperiodic treatment on the weekly variation of extention growth of "Rosō."

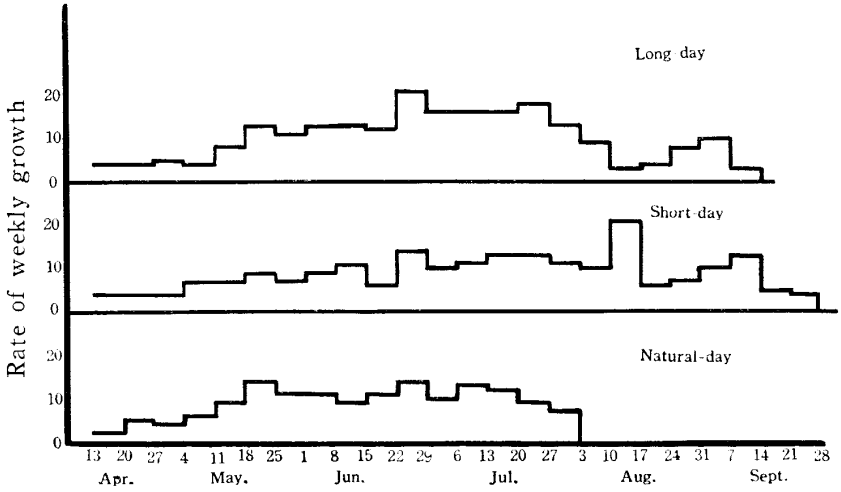

Fig. 3. Effect of photoperiodic treatment on the weekly variation of extention growth of "Okinawa."

treatment was conducted was 1 or 2° C higher than that of out-door, must be considered upon the discussion of growth. Also the period of stopping of growth was earlier in the natural-day lot than in that of other photoperiodic lots.

As to the form "Okinawa" the periods of stopping of growth of the three lots were contradictory, comparing with the case of form "Rosō." The delay of the period of stopping of growth in the short-day lot may owe to the higher temperature of 1～2° C mentioned above.

The shooting of the lateral branches of the seedling-A was fairly vigorous, while that of the grafted sapling of the "Rosō" was not so much as shown in Table 6. The number of the lateral branches was fewer in the short-day lot than those in other photoperiodic lots, similarly in the case of "Okinawa."

The mean length of the wattles of seedling-A was surely the largest in the long-day lot and the next in the natural-day lot and the shortest in the short-day lot (Table 5). It is interesting that the number of the lateral branches in both the form "Okinawa" and the seedling-A was little in wattles of the short-day lot than in those of the other photoperiodic lots.

The period of winter bud sprouting was investigated in spring of 1956 with the same materials mentioned above. The winter buds of the wattle growing under short photoperiod indicated that they almost reached "Taiseiki" (or a period when the upper half part of the winter bud turn to greenish) in the beginning of February; that was earlier than in those of the other photoperiodic lots. However, the sprouting buds did not arrive at "Dappoki" (or a period of taking off the bud scales) but scarcely reached "Pre-dappoki" (or a period prior to the "Dappoki") in the beginning of March. A half number of the winter buds of the wattles in the long-day lot showed the "Taiseiki" in the beginning of March, while in the natural-day lot only 4 to 5 buds arrived at it. But "Kaiyōki" (or a period when the first leaf grows horizontally) of the three lots agreed nearly in the same time.

Experiment IV—1 (in 1953)

Material and photoperiodic treatment were quite similar to those used in Exp. III—1.

In the case of the summer experiment (from the 25th of July to the 30th of August), 4 to 5 lower leaves of each wattle grown under three different photoperiodic

conditions defoliated in the same appearance on the 10th day after the onset of the photoperiodic treatments and henceforth no defoliation occurred.

On the other hand, in the autumn experiment (from the 15th of October to the 25th of November) as shown in Fig. 4, the defoliation was accelerated by the short photoperiod of 8 hours of light.

It is supposed from the above fact that, in autumn, a severe short photoperiodic procedure such as of 8 hours accelerates the defoliation, even if the duration of the short photoperiodic conditions is as fairly short as about one month. A fair concentrate defoliation in autumn as seen in next experiment (IV—2 and IV—3) may be concerned with the above fact.

The accelerating effect of the defoliation could not be seen in the summer experiment, even if the mulberry was exposed to the short photoperiodic conditions. The same observations were reported by Kramer[19]: the seedlings of *Liquidambar styraciflua* and *Quercus alba* retained their leaves even under natural short-day conditions in the greenhouse, although corresponding seedlings maintained out-doors dropped their leaves at the normal time. Similarly, seedlings of *Betula pubescens*, *R. pseudacasia* and *Acer pseudoplatanus* have been found to retain their leaves for long periods under short-days when maintained under warm conditions in a greenhouse.[20]

In the occurrence of defoliation phenomenon one can not disregard the effect of the lowering of the atmospheric temperature as well as the shortening of the daylength.

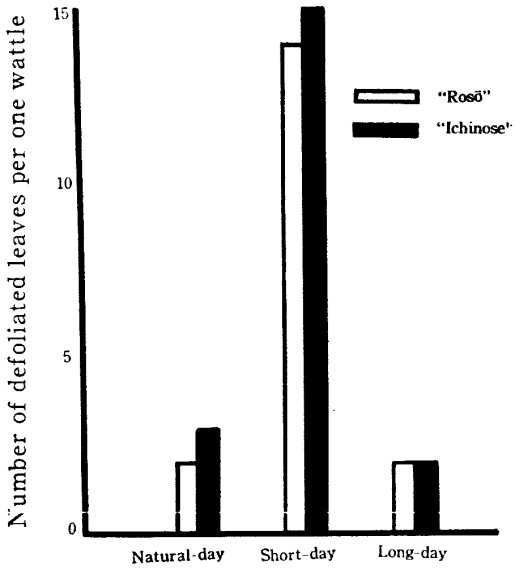

Fig. 4. Effect of photoperiodic treatment on the defoliation (in autumn).

Experiment IV—2 (in 1954)

Materials and photoperiodic treatments are the same as in Exp. II—1. The results obtained are shown in Figs. 5 and 6. The number of the defoliated leaves in the natural-day lot of the form "Rosō" was the largest compared with that of the other photoperiods up to July. The defoliation of the short-day lot was not so many up to October but an enormous defoliation took place in November. This fact agrees well with Exp. IV—1 in which fair defoliation was observed in autumn in the short-day (8 hours) lot.

The condition of the defoliation in the form "Okinawa" is varied much from that of generally cultivated varieties, the from "Rosō' etc., so that the former can not be regarded as the same with the latters. The period of the largest defoliation agreed with the case of the form "Rosō'' in which it was seen in October in the short-day lot.

The higher temperature in the dark room seemingly affected the materials in

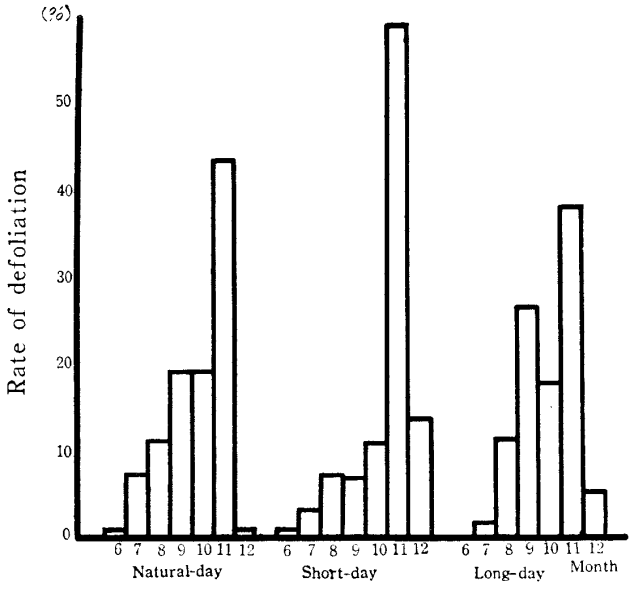

Fig. 5. Effect of photoperiodic treatment on the defoliation of "Rosō" (1954).

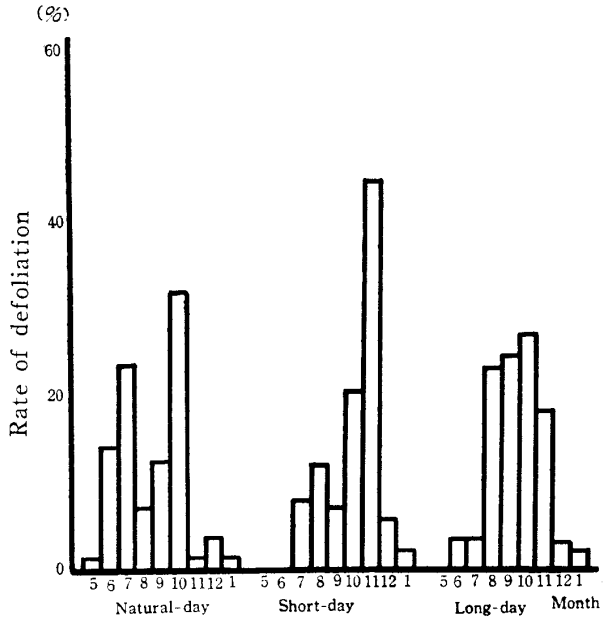

Fig. 6. Effect of photoperiodic treatment on the defoliation of "Okinawa" (1954).

the short photoperiodic condition, and let them to retain the leaves up to fairly late.

Experiment IV—3 (in 1955)

Materials used in this experiment were the same plants used in the Exp. IV—2.

In this time the material was in the condition of *Tatedōshi* following the Exp. IV—2, and was used for the observation of the defoliation as a two-year-old wattle.

The ratio of the defoliation, i.e. a ratio dividing the number of fallen leaves in a certain period by the number of total leaves, is as shown in Figs. 7 and 8.

Unfortunately, the authors could not help giving up the investigation after the 26th of September, because of the attack of the Thyphoon No. 22 on the 28th of September.

Almost similar tendency of the increase and decrease of defoliation was seen in three photoperiodic lots during the period of investigation. Comparing each plot, the defoliation of the short-day lot was not so remarkable and was less than that of the long- and natural-day lots from early June to late August, while a severe defoliation took place in mid Septmber. Though the severe defoliation of the wattle in the preceding year (the very year it was planted) occurred in November, that of the same material as the second-year-old in this year in September.

The percentages of the remaining leaves on the last day (the 26th of September) of the experiment, were 29, 24, and 30% in the natural, the short and the long day lots, respectively.

It seemed obvious that the decrease of the remaining leaves of the short-day lot was result of the severe defoliation in mid September.

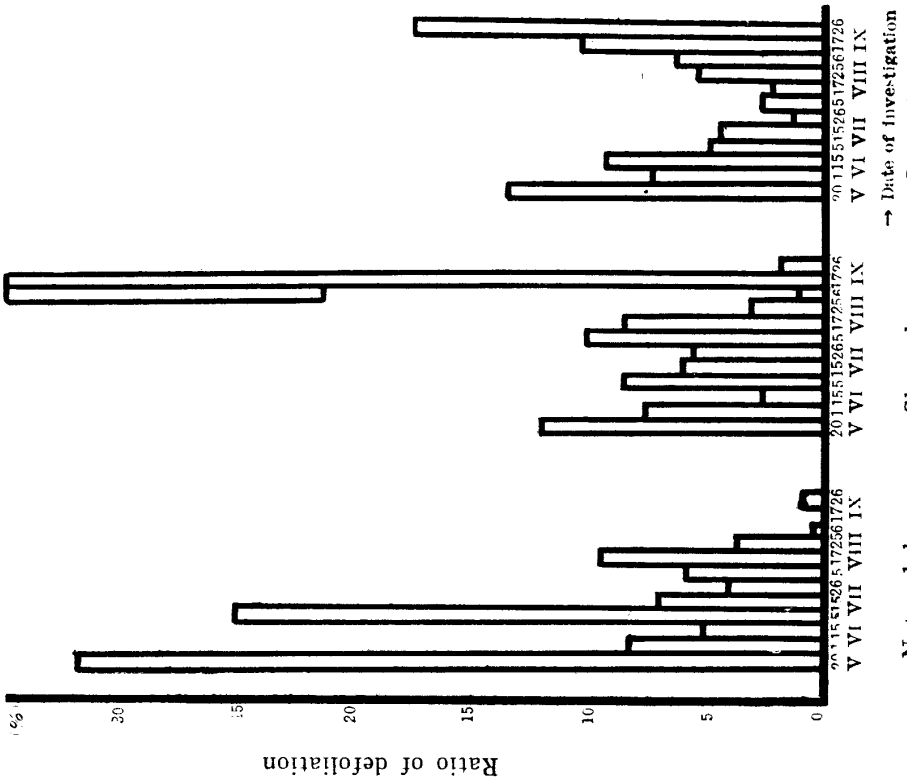

Fig. 8. Effetc of photoperiodic treatment on the defoliation of "Okinawa" (1955).

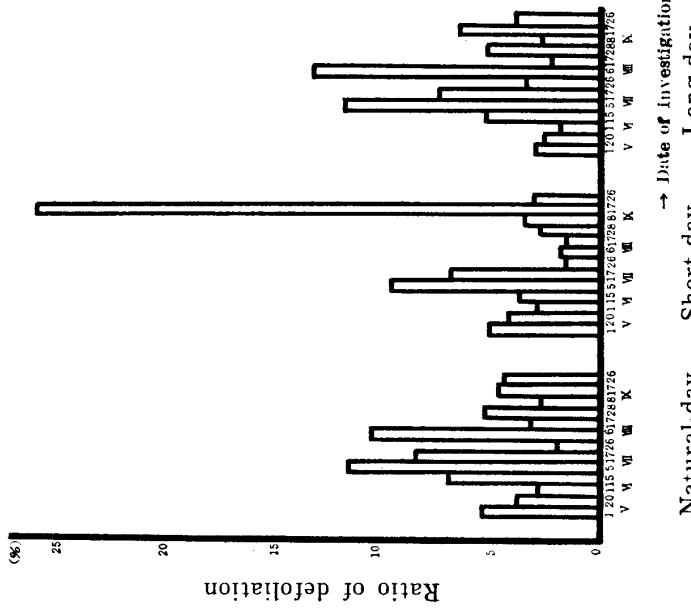

Fig. 7. Effect of photoperiodic tratment on the defoliation of "Rosō" (1955).

Comparing between the natural- and long-day lots of the form "Rosō," the increase and decrease of the defoliation was very variable concerning every investigated fractional period. However, as to the remaining leaves in late September, the difference between the two lots could be hardly observed. So the difference between the natural-and long-day lots might possibly occurred after late September. This consideration was also recognized by Exp. IV—2, in which the leaves of the long-day lot retained more than that of natural-day lot.

On the other hand, in the form "Okinawa" the defoliation takes place several times in a year as mentioned previously and it can not be compared with that of the form "Rosō." Percentages of the number of the remaining leaves of total leaves on the 26th of September are 0, 1 and 15 in the natural-, the short- and long-day, respectively. The long photoperiodic coditions seemingly suppressed the defoliation up to late September.

As to the defoliation, the form "Okinawa" seems fairly sensitive to the photoperiod. The similar fact could be seen also in Exp. IV—2, in which considerable numbers of leaves were remained on the 16th of December in the long-day lot.

An abundant defoliation took place in the natural photoperiodic lot from the early period of the experiment and on the material a symptom of dwarf disease was observed the next spring (which coresponded with the end of this experiment), so it was impossible to continue the observation and to clarify the reason of this defoliation.

A severe defoliation was seen also in the short-day lot in the middle of September, the time coinciding with that of conspicuous defoliation in the short-day lot of the form "Rosō."

III. Summary

The authors carried out the researches of the period of the floral formation of mulberry and also investigated on the effect of photoperiodic treatment on the reproductive and vegetative growth together with the defoliation.

1. The period of the floral formation in the form "Murasakiwase" of *Tatedōshi* (non-cutting) was about the beginning of June.

2. Under the condition of spring-cutting (*Harugari*) the period of the floral formation is different according to the forms, for example, an earlier form such as "Ōshima" produces the sufficient floral buds in late May, while later forms such as "Kairyōwasezyūmonji" and "Shiromekeisō" from the beginning to the mid of August. In general, in the majority of forms the floral primordia was seen from mid to late June.

3. In the case of summer-cutting (*Natsugari*) the period of floral formation is different according to the forms: "Shinsō-No. 1," "Yaechijira," "Rosō," "Ōhatawasezyūmonji" and "Jinsō" produce floral buds about one month after the cutting, whereas "Shimanouchi," "Shiromekeisō" and "Shūkakuichi" two months or more after the cutting.

4. The time of floral formation is partly connected with the intrinsic character of the form but is also controlled by the age after the plantation. Young trees

generally scarcely have floral primordia; but only the form "Enshūtakasuke" exceptionally flowered 4 years after the planting.

5. Comparing with the number of the floral buds of the mulberry growing under the natural, short and long photoperiods, the following results were obtained. The number of the floral buds of the wattle of the form "Rosō" of two-year-old after planting growing under the short photoperiod was more than that of the natural and long photoperiodic lots. However, the number of floral buds of the same material, in the third year after the plantation, was never superior to that of the two other photoperiodic conditions.

6. The influence of photoperiodic treatment on the increase in the number of floral buds of the form "Okinawa" belonging to the race "Shimaguwa," could not be seen.

7. The number of the floral buds of certain seedlings was maximum in the wattle growing under the conduction of short photoperiod in 3 and even 4 years after the planting.

8. It was observed that the short photoperiod increased the number of the floral buds in the form "Rosō" and the seedling (of unidentified form), at least in younger stage after the planting or sowing. However, this effectiveness of the photoperiodism became indistinct with the age of the plant.

9. Seedlings in the second year after the planting (three-year-old from the sowing), induced only male flowers on the wattle under the short photoperiod, but in the next year female flowers were also produced, mixed with male ones on the wattle, when short photoperiod was contiuned.

10. Seedlings vernalized with the low temperature of 5° C during 30 days as well as those not vernalized brought no floral formation until the second year after the plantation, even though they were controlled under one or the other photoperiodic tratment.

11. Generally speaking, although the number of the leaves attached to the wattle growing under the long photoperiod was fewer than that of two other photoperiodic plots, the wattle length of the former showed the largest value and that of natural-day the second and that of short-day the smallest. However, as to the form "Okinawa" the wattle length of short photoperiodic lot was superior to that of natural-day lot, seemingly according to the influence of the higher temperature of 1 or 2° C in the dark room which was used for the short photoperiodic treatment.

12. The internode was longer in the wattle growing under the long-day than that of the two other photoperiodic treatments.

13. The period of arrest of growth in the form "Rosō" treated under each of three photoperiods, occurred almost simultaneously in mid or late September, while in the case of the form "Okinawa" that of the natural-day lot was earlier and that of the short-day lot was the latest.

14. The number of the lateral branches in the form "Okinawa" of short photoperiod was fewer than that of other photoperiodic treatment.

15. In summer, the accelerating effect of short-day (severe such as 8 hrs.) on the defoliation could not be seen; however, in autumn, the same photoperiodic treatment, though the duration was only about one month, accelerated the defoliation.

16. The long photoperiodic treatment restrained the defoliation in the form "Okinawa."

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