

# STUDIES ON PHOTOTAXIS IN THE SILKWORM, BOMBYX MORI L.

## 1. Differences of Phototactic Responses among the Newly Hatched but Unfed Larvae of Some Varieties\*

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### INTRODUCTION

It is well known that domesticated silkworms, with the exception of the earliest larval and especially the egg stages, are not so sensible to light stimuli. According to the observations by many scholars, the phototactic response in the larval stage of silkworms tends to decrease as they grow, but an increase can, more or less, be seen at the oldest instar (YOSHIIKE, 1899; KELLOGG, 1907; ACQUA, 1916; KIMURA, 1917; YAGI, 1923 a b; KIKKAWA, 1948; KOIZUMI, 1950, 1951 a b, 1955; MIYAGAWA, 1951-1953). In the newly hatched silkworms but unfed, however, the reverse phototaxis to negative from positive occurs in a few varieties and hybrids under a gradient of light intensity (MIYAGAWA, 1951, 1952). Such a phenomenon was also ascertained by the senior author in the preliminary report (1959).

This report enlarges on the extensive knowledge of differences and changes of the phototactic reaction in the newly hatched larvae of *Bombyx mori* among varieties and under a light gradient, respectively.

Before going further the authors desire to acknowledge their indebtedness to Dr. N. YAGI for his kind advices. Thanks are also due to Dr. E. NAGASHIMA, who gave the materials for the work.

### MATERIALS AND METHODS

The newly hatched but unfed larvae used for the test are totally eleven varieties in four races. They are generally named "Normal Strain" and are shown in Table 1.

Each group of 100 individuals having been confined under the condition of 15°C, R. H. 74% and darkness for five hours after hatching, were subjected to the different light intensities; 0, 10, 20, 30, 50, 70, 100, 150, 200, 300, 400 and 500 luxes, respectively for 10, 30 and 60 minutes. The light through a screen to absorb the heat energy was casted at the larvae, which were set on a white paper, with 70 cm-width from the horizontal direction and resulted distribution of the larvae was recorded.

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Table 1 Characters of the varieties used for the test.

Race Variety	Voltinism	Larval pattern	Cocoon	Remarks
Japanese				
<i>Koishimaru</i>	Uni-	Normal	White, peanut shape	Pure blood
<i>Nichi No. 1</i>	Uni-	Normal	White, peanut shape	Pure blood
<i>Nichi No. 122</i>	Bi-	Normal	White, a little loosened peanut shape	Extracted from the hybrid (Chin. × Eur.)
<i>Okusa</i>	Bi-	Normal	White, peanut shape	Pure blood
Chinese				
<i>Shi No. 4</i>	Uni-	Plain	White, round or ellipsoid	Pure blood
<i>Shi No. 108</i>	Bi-	Plain	White, round or ellipsoid	Extracted from the hybrid (Chin. × Chin.)
<i>Shi No. 122</i>	Bi-	Plain	White, round or ellipsoid	Extracted from the hybrid (Chin. × Chin.)
<i>Daizō</i>	Bi- (or more)	Normal	Yellowish green, spindle shape, soft	Pure blood
European				
<i>Ō No. 18</i>	Uni-	Plain	White, ellipsoid	Pure blood
Indo-Chinese				
<i>Cambodge</i>	Multi-	Plain	Yellow, spindle shape, soft	Pure blood
<i>Mysore</i>	Multi-	Plain	Somber white, spindle shape, soft	Pure blood

The 150 watt fluorescent lamp (Fuji Projection Lamp) was used for the light source, the intensity being measured by the photometer (Toshiba No. 5).

## RESULTS AND CONSIDERATION

### I. Japanese Race

#### 1. *Koishimaru* (Fig. 1 and Fig. 2)\*

Up to the present, a study with the similar purpose as this work has been done on the same larvae under the condition of 25°C by MIYAGAWA (1951). So the authors carried out the experiment, in comparison with it, under the lower and the higher thermal conditions of 17°C, R. H. 94% and 28°C, R. H. 80%, respectively.

In the former case (Fig. 1), most of the individuals act photopositively from 10 lux to 200 lux, while the photonegative larvae gradually increase from more than 150 lux. It is assumed that the critical range of light intensity to cause the phototactic reversal exists within 200~300 lux (see Fig. 4).

The total distance of movements of the phototactic larvae is well coincided with changes of the number of the larvae, maximum being about 130 cm either at 70 lux in the positive side or at 500 lux in the negative one.

In the latter case (Fig. 2), the larval activities are greatly exaggerated

\* In the case of darkness (0 lux), neither phototaxis, positive nor negative should be arisen, but the number of individuals in each half field divided by a certain line are shown in percentage. The same treatment will also appear in the succeeding figures.

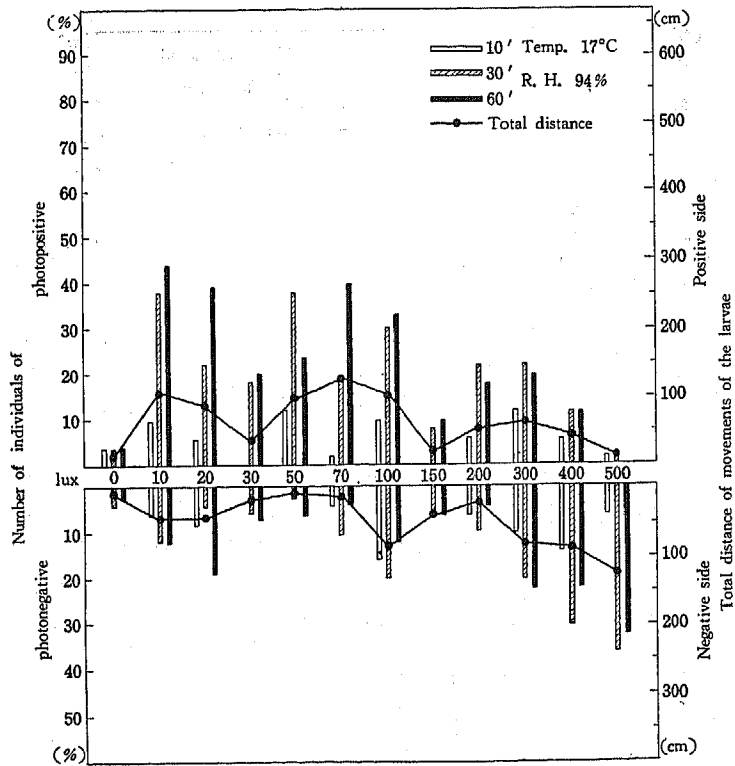


Fig. 1 Phototactic response of *Koishimaru* under lower temperature.

either positively or negatively in phototaxis. This will be a result caused by the temperature shift. Most larvae show the photopositive response from 10 lux to 30 lux, but the tendency changes towards the negative from 50 lux and above excepting 150 lux and 200 lux régimes, in which the number of individuals becomes slightly larger in the positive field than in the negative one. Under the thermal condition of 25°C (MIYAGAWA, 1951), the larvae were lower in activity at 100 lux and the phototactic reversal to negative from positive occurred near at 100 lux, while in this 28°C régime, it did, being more hastened, within 50~70 lux (see also Fig. 4).

The largest total distance of movements of the larvae is hardly different between the positive direction and the negative one, being about 400 cm at 10 lux and -430 cm, respectively. The larvae are not so active in the absence of light.

In each light treatment the phototactic reaction of the newly hatched larvae are not limited in one way, positive or negative, and some are usually inactive. Then the alternative excess between the numbers of individuals (%) observed in the positive field and the negative one after illumination for 60 minutes has been taken as "Phototactic value".

Under the temperature of 17°C, the maximum value shows 38% at 70

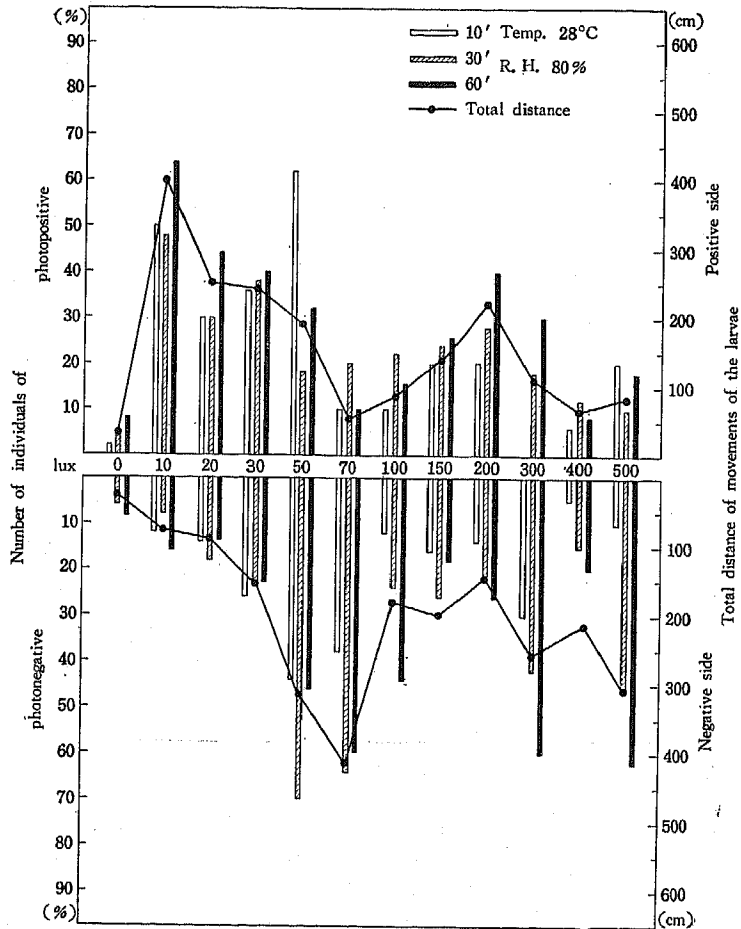


Fig. 2 Phototactic response of *Koishumaru* under higher temperature.

lux in the positive side, being  $-30\%$  at 500 lux in the negative one and the critical intensity which causes the phototactic reversal is indicated to exist near at 300 lux, but under  $28^{\circ}\text{C}$ , it shows  $48\%$  at 10 lux in the positive side,  $-50\%$  at 70 lux in the negative one. The above critical point is assumed to lie near at 60 lux (see Fig. 4).

## 2. *Nichi No. 1* (Fig. 3)

The larvae show rather photopositive reaction in lower intensities (10~20 lux), but turn markedly to photonegative from 30 lux. The negative response has originally been maintained in higher ranges of light intensities and the number of the individuals photonegative inclines to increase till 200 lux accompanying with the time of illumination. Few photopositive larvae are observed in 150 lux and more, within which the activity of the larvae seems to be repressed by intensified light.

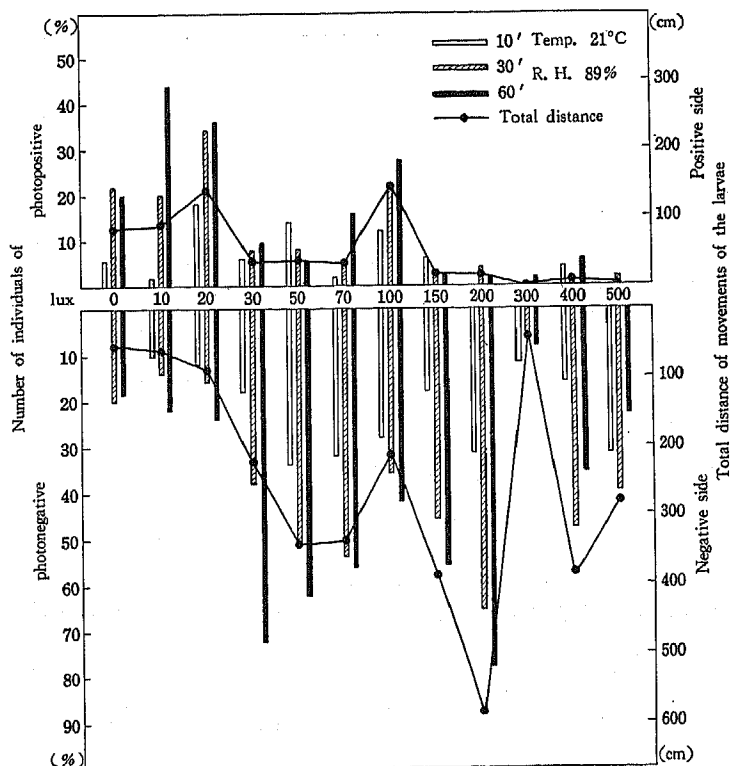


Fig. 3 Phototactic response of *Nichi No. 1*

The total distance of dispersions of the phototactic larvae is most at 100 lux (150 cm) in the positive side and at 200 lux (about 570 cm) in the negative one; the larvae show lesser activity in the former than in the latter. The mobility in dark condition is quite large, the distance of movements being 50~80 cm.

The largest phototactic value is  $-76\%$  at 200 lux in the negative phototaxis but no more than  $22\%$  at the lowest intensity (10 lux) in the positive one. The critical intensity which causes the phototactic reversal is strictly limited within 20~30 lux (perhaps near at 25 lux) under the condition of  $21^{\circ}\text{C}$  (Fig. 4.)

### 3. *Nichi No. 122* (Fig. 5)

In lower intensities, particularly in 20 lux, the photopositive reaction is so much significant as in the case of *Nichi No. 1*. It reverses, however, to the negative within 30~50 lux. The critical range of the reversal change exists at much lower intensity than *Koishimaru* (Fig. 1, 4).

The total distance of migrations of the larvae is most at 20 lux (about 180 cm) in the photopositive field while at 300 lux (about 310 cm) in the photonegative one, showing to be more active in the photonegative response. The activity is large even in the absence of light, the total distance being

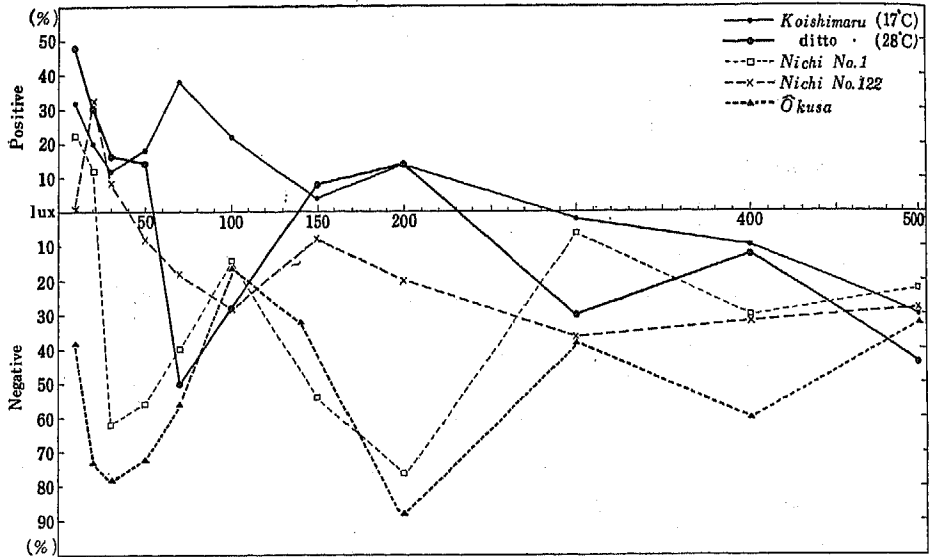


Fig. 4 Phototactic values (%) of four varieties in Japanese race.

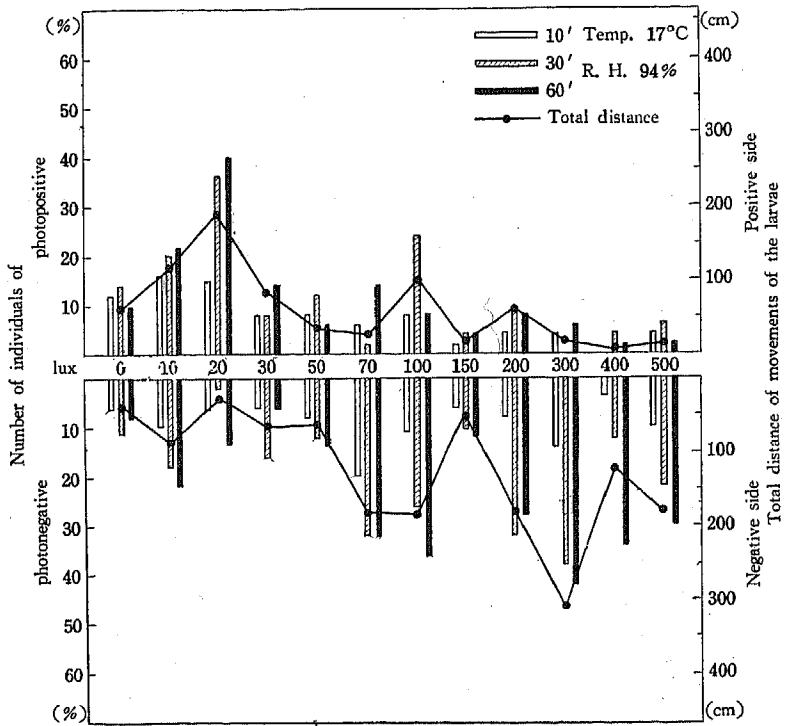


Fig. 5 Phototactic response of *Nichi No. 122*.

40~60 cm under the temperature of 17°C.

The phototactic value is maximum (32%) at 20 lux in the positive side and that (-36%) at 300 lux in the negative one. The critical point, at which the phototactic reversal appears, is presumed to exist approximately at 40 lux (Fig. 4). Taking the thermal difference into consideration, the critical point of this variety can be said to stand at almost same intensity as *Nichi No. 1*.

#### 4. *Okusa* (Fig. 6)

The larvae present the most typical photonegative response. The reverse change to the positive direction can not be seen at every light intensity.

The activity is affected conspicuously by light; the longest total distance of movements of the larvae reaches extremely about 1170 cm at 30 lux in the negative side though 250 cm at 10 lux in the positive side. Such a strong one side but quite opposite phototaxis to this variety has also been detected in *Chocolate*, a mutant of Japanese race (MIYAGAWA, 1951), in which the phototactic change to the negative field did not take place even at 500 lux. The mobility under darkness is remarkable, the total distance of movements showing 50~90 cm as much as *Nichi No. 1*.

The phototactic values are all negative, the largest being -88% at 200 lux and the smallest -16% at 100 lux (see Fig. 4).

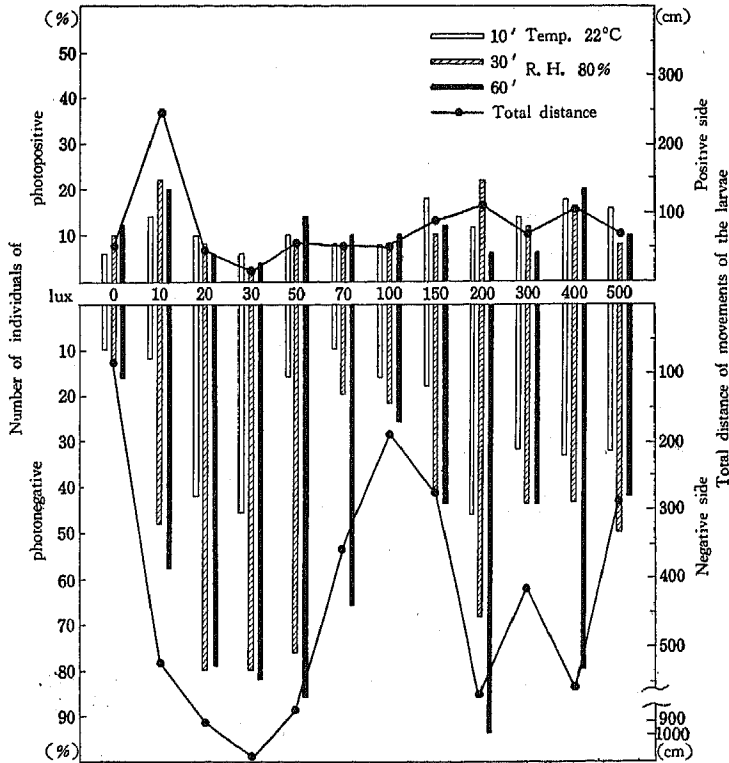


Fig. 6 Phototactic response of *Okusa*.

## II. Chinese Race

### 1. *Shi No. 4* (Fig. 7)

The larvae are quite inactive to light stimulation. At 10 lux the positive phototaxis appears in 40% of individuals subjected to the light, but it tends to reverse towards the negative one with intensifying light irradiation. The photonegative response occurs from 70 lux to 100 lux though changes again to the positive from 150 lux and more. Therefore it is indicated that the larvae have an indefinite phototaxis in higher light intensities more than 100 lux.

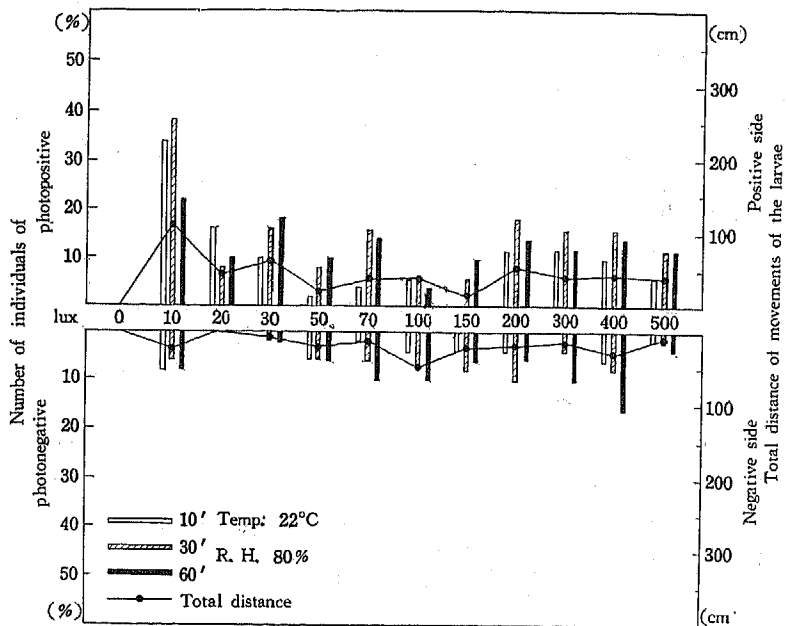


Fig. 7 Phototactic response of *Shi No. 4*.

The largest total distance of movements of the larvae is about 110 cm at 10 lux in the photopositive side, while about 60 cm at 100 lux in the photonegative side. It will be perceptible that the larval response to light is rather higher in the positive direction than in the negative one. No active larvae are found in the absence of light.

The phototactic value is 4~16% in the positive side while -2~-6% in the negative one. The first reversal of phototaxis to the negative from the positive takes place probably at about 80 lux (see Fig. 9).

### 2. *Shi No. 108* (Fig. 8)

The larvae manifestate highly photopositive response in lower intensities and no photonegative individuals are seen. At 30 lux, however, the activity of the larvae fall suddenly down accompanying with a small increase of the



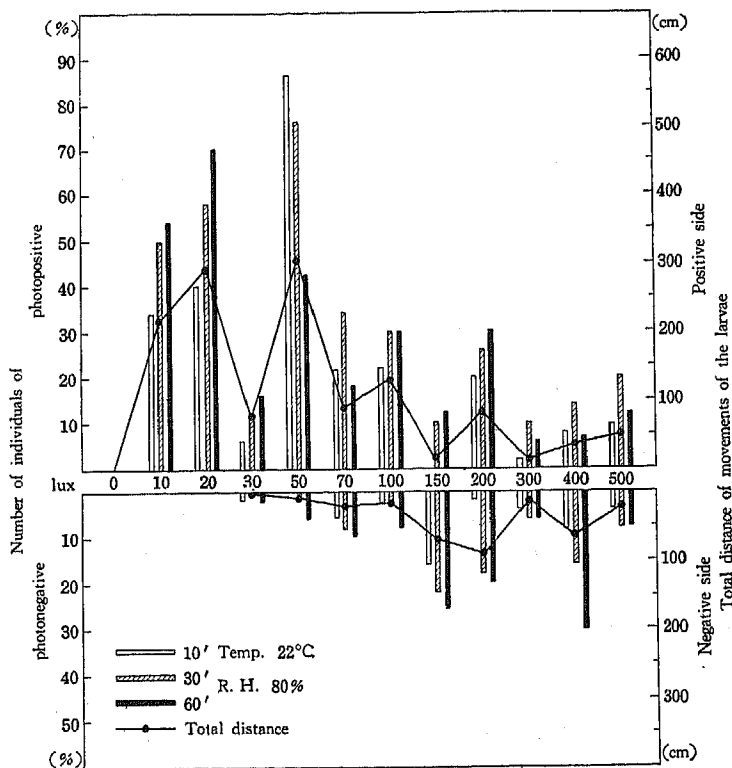


Fig. 8 Phototactic response of *Shi No. 108*.

photonegative individuals. The number of the larvae showing the positive phototaxis is most (82%) at 50 lux, but the larvae which move towards the negative field gradually increase as time went. The reverse change of phototaxis occurs within 100~150 lux, above which the larvae do not show the fixed phototaxis, positive or negative, and the difference between the larval numbers in the both fields becomes not so evident. It can be accepted that the larvae do not exhibit the definite phototactic reaction from 150 lux and above. Such a tendency is almost similar to the case of *Nichi No. 4*, whose activity to light stimulation being much lower than the present variety.

The largest total distance (maximum) of movements of the larvae is about 300 cm at 50 lux in the positive side while about 90 cm in the negative side, the mobility being much larger in the former than in the latter. Any active larvae are not observed in the dark field.

The largest phototactic value is 70% at 20 lux in the positive field and -18% at 400 lux in the negative one.

The first critical point to cause the reversal of phototaxis exists presumably near at 130 lux and that of the second at just 300 lux (Fig. 9).

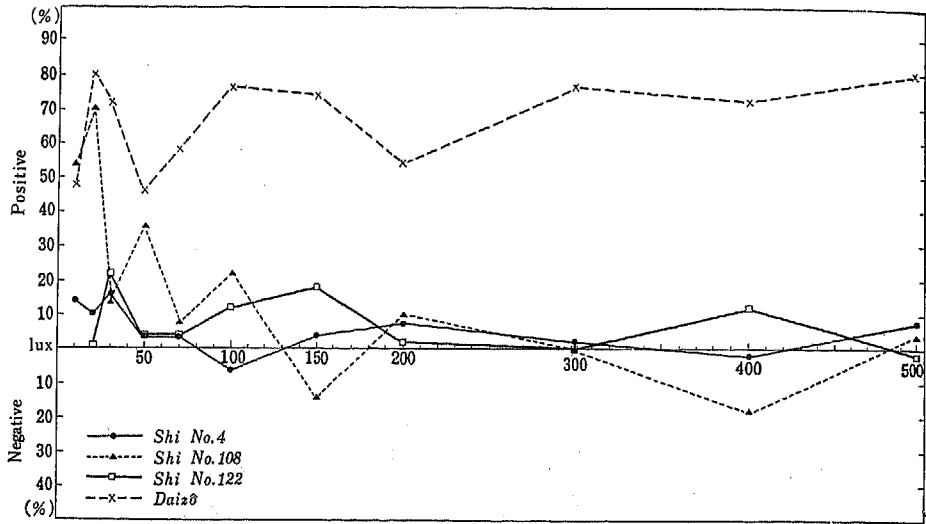


Fig. 9 Phototactic values (%) of four varieties in Chinese race.

### 3. *Shi No. 122* (Fig. 10)

The larvae are much insensible to light stimulation, but the activity is more or less raised within 30~150 lux and at 400 lux. Even at 400 lux only 25% of the treated individuals go to the positive direction after one-hour-illumination. Simultaneously the number in the negative field increases to reach 12%.

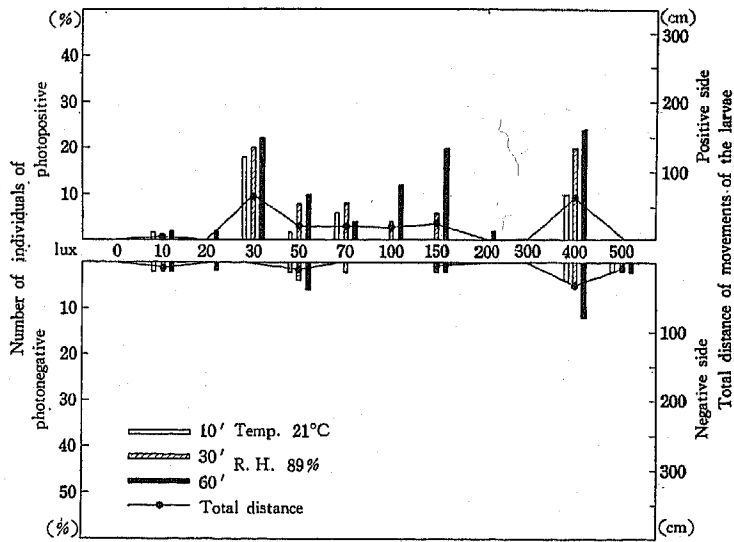


Fig. 10 Phototactic response of *Shi No. 122*.

The total distance of movements of the larvae shows maximum (65 cm) at 30 lux in the positive field while that (35 cm) at 400 lux in the negative one. It is probable that the larvae have the photopositive responsibility, hardly showing any reversal of the phototaxis, but there is an implication of existence of the reversal at 300 lux (Fig.9). All the larvae confined in the dark room show no movement.

4. *Daizō* (Fig. 11)

The most typical positive phototaxis appears in all light intensities, few individuals exhibiting the photonegative reaction. The number of the larvae in the positive field show an upward tendency accompanying with the time of illumination. Such one side phototaxis could not be observed not only in the aforementioned Chinese varieties but also in the other Chinese ones i.e. *Gantai* and *Ryūkyūtananken* (MIYAGAWA, 1951), in which the reverse phototaxis to negative from positive occurred at about 30 lux. This phototactic sign will be rather resemble to *Chocolate*, a mutant of Japanese race (MIYAGAWA, 1951).

The total distance of movements of the photopositive individuals in each light condition is quite longer (140~370 cm) but not so conspicuous the

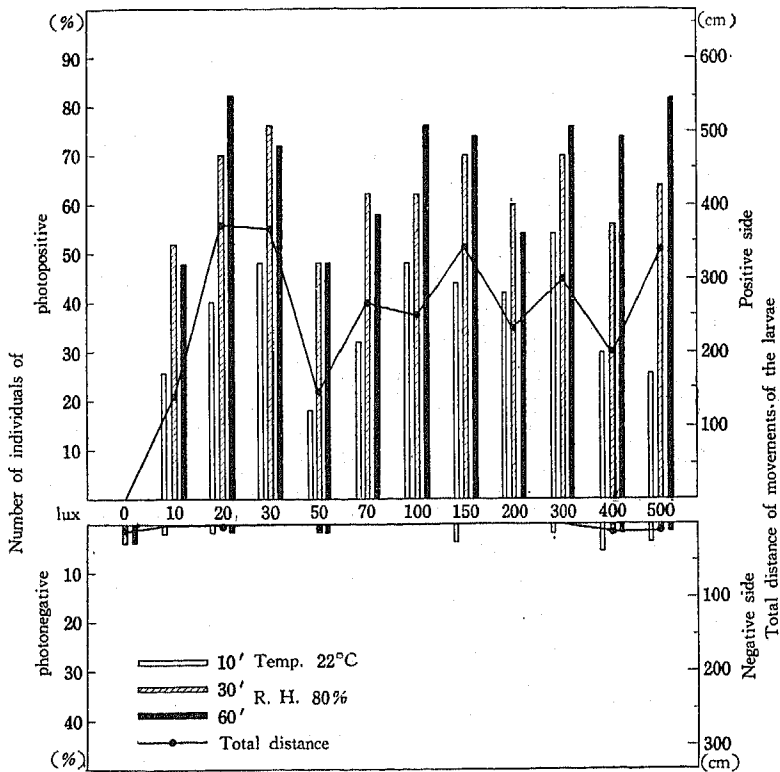


Fig. 11 Phototactic response of *Daizō*.

difference which is caused by the light action. The larvae are characterized by immobility under darkness contrasted with the highest dispersive reaction under illumination.

The phototactic values are all positive; about 50% (minimum) at 10 lux and 50 lux, and about 80% (maximum) at 20, 100, 300 and 500 luxes (see Fig. 9).

### III. European Race and Indo-Chinese Race

#### 1. *Ö No. 18* (Fig. 12)

This variety and the succeeding two varieties belong to European and Indo-Chinese races, respectively.

In the present variety considerable number of the larvae disperses either towards the photopositive or towards the photonegative sides, but much more individuals migrate to the positive than to the negative within 10~150 lux, from which the tendency takes the opposite direction. In 150 lux and more the number of individuals of the photopositive side decreases more obviously in one-hour-illumination than in half-an hour-one, while that of the negative side inclining to increase. The critical range of phototactic reversal is presumed

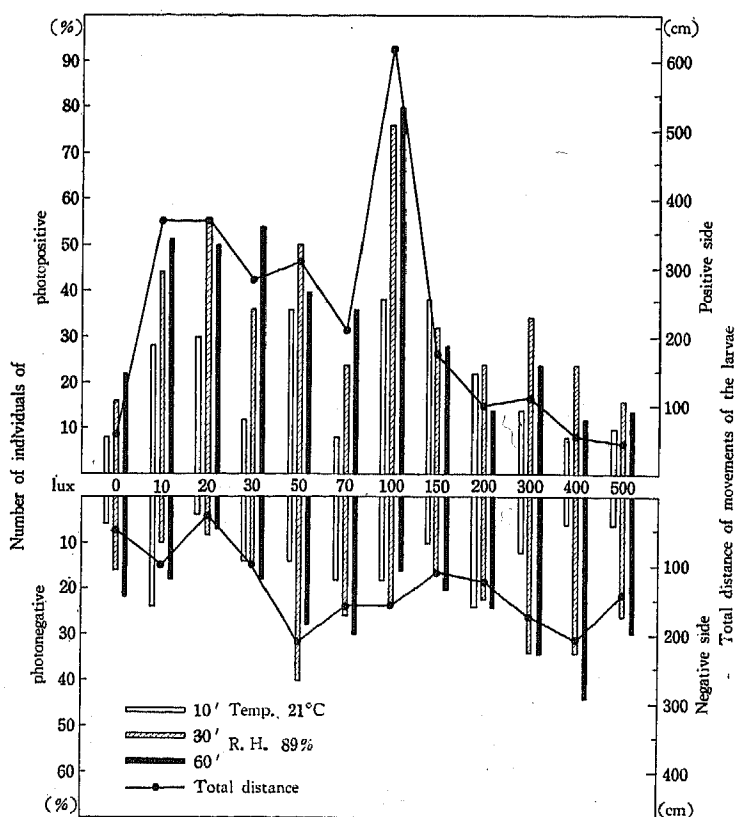


Fig. 12 Phototactic response of *Ö No. 18*.

to lie within 150~200 lux (Fig. 13). This range almost coincides with the previous paper's.

The maximum value of total distance of movements of the larvae is about 620 cm at 100 lux in the positive side, while in the negative one approximately 200 cm at 50 and 400 luxes, so the mobility is sure to be larger in the former than in the latter.

The larvae are well characterized by a large activity in the absence of light, even where about 50 cm-movement has been recorded.

The phototactic value in the positive side is 64% (the greatest) at 100 lux, the next 44% at 20 lux, but in the negative one -32% is the largest value (Fig. 13). The critical intensity which causes the phototactic reversal can be seen to exist near at 170 lux.

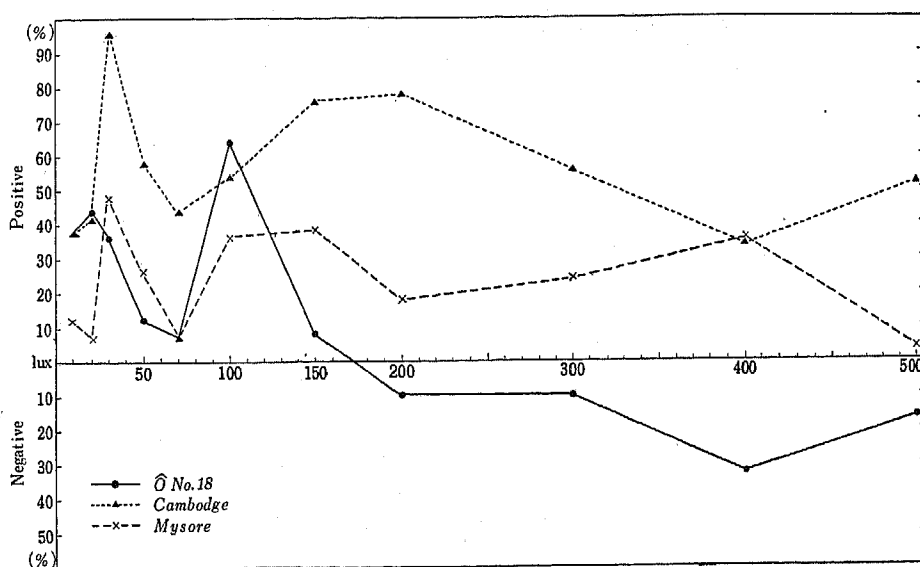


Fig. 13 Phototactic values (%) of European and Chinese races.

## 2. *Cambodge* (Fig. 14)

The larvae show a typical and strong photopositive reaction particularly near 30~300 lux. The larval number (%) reaches 98 and 82 at 30 lux and 200 lux in the positive field, respectively, but almost zero in the negative one. Generally the photopositive individuals in each light régime appears to increase as the time of irradiation becomes longer, the tendency being the most salient at 30 lux.

The total distance of movements of the larvae is longest (about 720 cm) at 150 lux in the positive direction, but in the negative one the largest is only 40 cm at 70 lux and 500 lux.

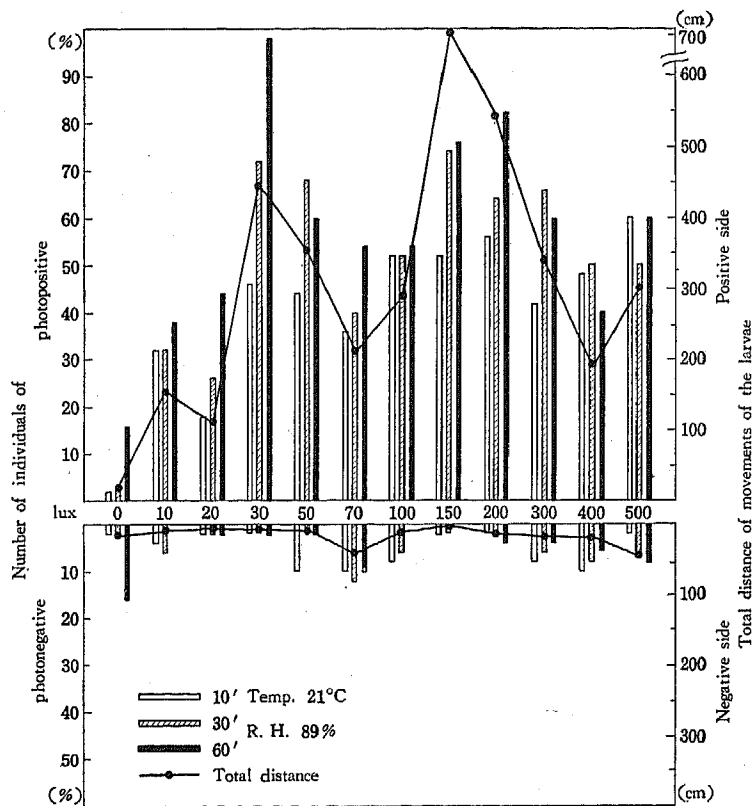


Fig. 14 Phototactic response of *Cambodge*.

The mobility in dark condition is not so evident, the total distance being 20 cm.

The phototactic value is smallest (30~40%) at 400, 10, 20 and 70 luxes (see Fig. 13).

### 3. *Mysore* (Fig. 15)

The larvae show faint activity to the light irradiation at 20 lux and lesser, but the phototaxis is undoubtedly positive. The clear positive phototaxis is seen from more than 30 lux excepting 500 lux, at which the taxis falls down in either positive or negative directions.

The phototaxis and mobility, especially in the latter under darkness, are weaker as compared with the former variety; the total distance of movements of the larvae is only about 140 cm (maximum) at 50 lux in the positive direction and about 50 cm (maximum) at 400 and 500 luxes in the negative one. Any individuals are not movable in the dark condition.

The phototactic values are all positive, the largest being about 50% at 30 lux and the smallest about 0% at 500 lux (see Fig. 13).

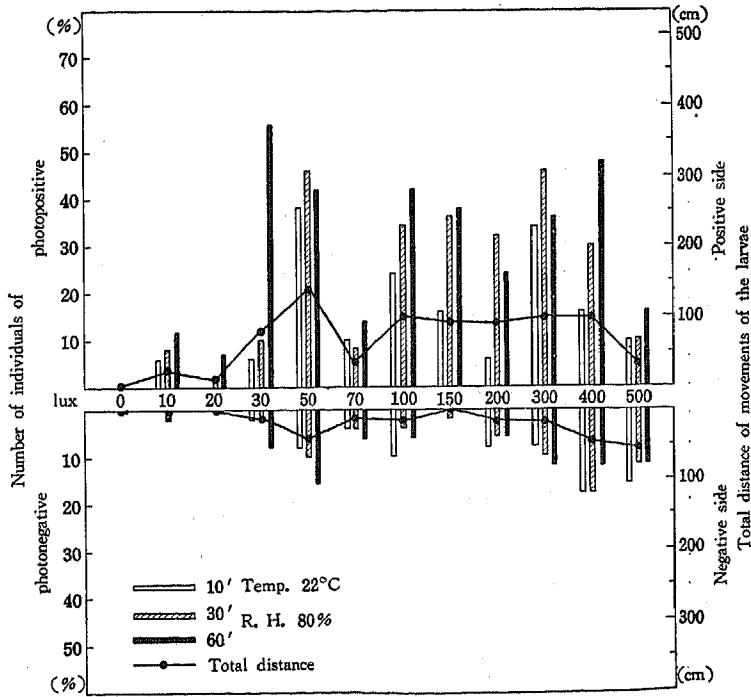


Fig. 15 Phototactic response of *Mysore*.

#### IV. Differences of Phototaxis among the Varieties

As aforementioned, it is obvious that manifestation of phototaxis differs considerably among races and varieties. We can classify it principally into four main types; the one ( $\oplus \rightarrow \oplus$ ), in which the larvae keep constantly photopositive response through whole light gradient, the next ( $\ominus \rightarrow \ominus$ ) which is quite opposite to the former in the phototaxis and the other ( $\oplus \rightarrow \ominus$ ) in which the reversal of phototaxis to negative from positive takes place at a certain light intensity. According to such a classification *Daizō*, *Cambodge* and *Mysore* belong surely to Type  $\oplus \rightarrow \oplus$ , *Ōkusa* to Type  $\ominus \rightarrow \ominus$ , and the other varieties to the rest type  $\oplus \rightarrow \ominus$ . Three Chinese varieties can be classified in Type  $\oplus \rightarrow \oplus$ , because these are changeable in phototaxis and firstly belong to Type  $\oplus \rightarrow \ominus$ , after this time reversing again to the positive phototaxis ( $\ominus \rightarrow \oplus$ ).

According to Table 2, in which chief results of this study are summarized, it can be recognized that European race and Japanese one (excepting *Ōkusa*) belong to Type ( $\oplus \rightarrow \ominus$ ), but the latter is stronger in the negative phototaxis than the former. The fact is well indicated by differences between the critical intensities and between the maximum values in the both races.

Chinese race (excepting *Daizō*), belonging to Type  $\oplus \rightarrow \oplus$ , is assumed to have originally the positive but weak phototaxis. It, however, has been

Table 2 Main differences of phototaxis among the varieties.

Race	Variety	Type of phototaxis	Critical intens. of phototac. reversal	Max. value of phototaxis		Dist. of movements in darkness	Largest dist. of movements		Condition	
				Posi- tive	Nega- tive		Posi- tive	Nega- tive	Temp.	R.H.
			lux	%	%	cm	cm	cm	°C	%
Japanese	<i>Koishimaru</i>	⊕→⊖	{200~300 50~70	40	30	10~20 25~30	130 400	130 430	17 28	94 80
	<i>Nichi No. 1</i>	⊕→⊖	20~30	20	80	50~80	150	570	21	89
	<i>Nichi No. 122</i>	⊕→⊖	30~50	30	40	40~60	180	310	17	94
	<i>Okusa</i>	⊖→⊖	—	—	90	50~90	250	1170	22	80
Chinese	<i>Shi No. 4</i>	⊕→⊕	70~100	20	10	0	110	60	22	80
	<i>Shi No. 108</i>	⊕→⊕	100~150	70	20	0	300	90	22	80
	<i>Shi No. 122</i>	⊕→⊕	300?	20	2	0	70	40	21	89
	<i>Daizō</i>	⊕→⊕	—	80	—	0~10	370	10	22	80
European	<i>Ō No. 18</i>	⊕→⊖	150~200	60	30	50~60	620	210	21	89
Indo-Chinese	<i>Cambodge</i>	⊕→⊕	—	50	—	20	730	40	21	89
	<i>Mysore</i>	⊕→⊕	—	100	—	0	140	50	22	80

reported by MIYAGAWA (1951) that *Gantai* and *Ryūkyūtasanken* belonging to the same race show a true reverse phototaxis (⊕→⊖) as same as Japanese race. Indo-Chinese race (⊕→⊕) has certainly one side phototaxis.

The silkworms may be divided into two groups, active and nonactive, from the view of the activity in darkness. Japanese and European races belong to the former while Chinese and Indo-Chinese races to the latter. The movements under illumination, however, correspond not always to the above grouping, as shown in the largest distance of movements. The authors' results concerning the activity are almost coincided with those of the past works (KOIZUMI, 1950~1955; MIYAGAWA, 1951, 1952), in which an order of the larval mobility under lower irradiation than 15 lux was introduced as follows.

European race > Japanese race > Chinese race

In Japanese race, *Nichi No. 1* and *Okusa*, being different from each other in the phototactic type, have a close formal similarity in changes of the phototactic values (see Fig. 4) under a light gradient. It will be noteworthy that the phototactic value in every variety falls remarkably down 100~150 lux (Fig. 4), but the reason remains unexplained. *Koishimaru* may be characterized by the lowest phototaxis of all Japanese varieties even if a reflection is taken on the difference of the thermal condition, to which the larvae were subjected. It is *Okusa* that exhibits the peculiar type of phototaxis which has not hitherto been discovered in any first instar larvae of *Bombyx mori*. Therefore *Okusa* can be concluded, from the phototactic point of view, to



stand far relationship from the varieties of other races but not so far kin from Japanese varieties.

In Chinese race *Daizō* presents an extreme difference on phototactic response to light from the other varieties. Speculating from phototactic feature this variety seems to sit somewhat closer kinship to Indo-Chinese race than Chinese race. *Shi No. 108* displays the highest activity to light among Chinese varieties with exception of *Daizō*.

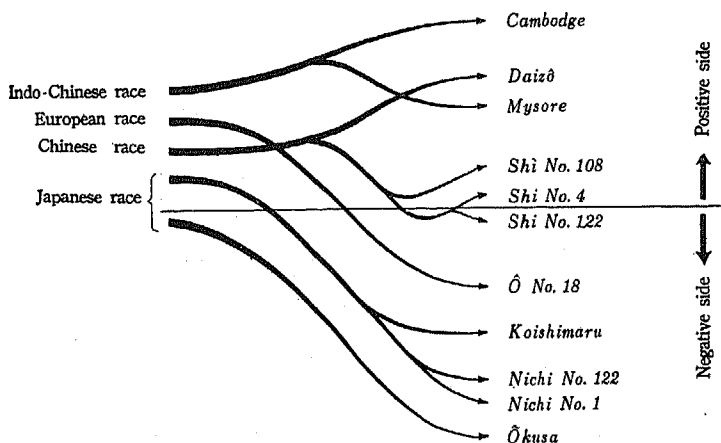


Fig. 16 Diagrammatic explanation of the kinship among varieties, considered from phototactic standpoint.

European race (only *Ô No. 18* being used) has a resemblance to Japanese race in the phototactic type and in the mobility under darkness, but is recognized to show higher range in the critical intensity, which causes the phototactic reversal, than Japanese race, so the latter is stronger than the former in the negative taxis.

In Indo-Chinese race *Mysore* has more or less lower phototaxis than *Cambodge*. Its immobility in dark condition exposes that the variety is put at a close kin to Chinese race.

In Fig. 16 a presumption will diagrammatically be given on mutual kinships among the varieties from the view of phototactic response.

Generally phototactic differences unlikely exist between uni- and bivoltine strains, but the photopositive character appears to be stronger in the varieties of more than bivoltine.

#### V. Peculiarity of Phototaxis of the Newly Hatched but Unfed Larvae of Silkworms

That the *Bombyx* larvae show a positive phototactic response has been known since considerable olden times (YOSHIIKE, 1899; KELLOGG, 1907; ACQUA,

1916: YAGI, 1923 ab). But in these studies any attention was not paid to phototactic reversal or change owing to growth stage or physiological conditions of the larvae.

Among insects, for example, *Vanessa* caterpillar (OEHMIG, 1939) presents constantly photopositive behaviour while *Ephestia* (BRANDT, 1934) and Mucid larvae (WIGGLESWORTH, 1953) keeping photonegative one through all larval stages. Many instances, however, have been reported of the reverse phenomenon of phototaxis to negative from positive ( $\oplus \rightarrow \ominus$ ) as larvae grow. We call it  $\oplus \rightarrow$  (growing)  $\rightarrow \ominus$  type of phototaxis, to which *Lymantria* (BRANDT, 1937), *Listroderes costirostris obliquus* (SUGIYAMA & MATSUMOTO, 1955, 1957, 1959 ab; MATAUMOTO, 1960), *Scopura longa* (KOMATSU, 1956), *Smerinthus ocellata* (RUITER & HORN, 1957) and *Aedes aegypti* larvae (OMARDEEN, 1957) belong. The first instar larvae of silkworms are said to exhibit the same response (MIYAGAWA, 1952; KOIZUMI, 1954).

Feeding, repletion or other physiological conditions bring also the phototactic reversal or change in some insects. Several examples are shown in the followings.

- Porthesia (Euproctis)* larvae..... LOEB (1889)  
 Phototactic type  $\oplus \rightarrow$  (feeding)  $\rightarrow$  disappear
- Chilo suppressalis*, newly hatched larvae..... KABURAKI et al. (1939)  
 Phototactic type  $\oplus \rightarrow$  (repletion)  $\rightarrow \ominus$
- Culicoides circumscriptus*, larvae..... BECKER (1957)  
 Phototactic type  $\ominus \rightarrow$  (repletion)  $\rightarrow \oplus \rightarrow$  (feeding)  $\rightarrow \ominus$
- Listroderes costirostris obliquus*..... MATSUMOTO (1960)  
 Newly hatched, previously unfed larvae  
 Phototactic type  $\oplus \rightarrow$  (feeding)  $\rightarrow$  inactive  
 The fourth instar larvae  
 Phototactic type  $\ominus \rightarrow$  (hunger)  $\rightarrow \oplus$
- Glossia*, adults..... JACK & WILLIAMS (1937)  
 Phototactic type  $\oplus \rightarrow$  (40°C)  $\rightarrow \ominus$
- Eristalis*, adults..... DOLLEY et al. (1947, 1951)  
 Phototactic type  $\ominus \leftarrow$  (10°C)  $\leftarrow \oplus \rightarrow$  (30°C)  $\rightarrow \ominus$
- Polydora pulchra*, larvae..... RANADE (1957)  
 Phototactic type  $\ominus \leftarrow < 3.25\%$  (Sanity)  $3.26\% \leftarrow \rightarrow \oplus$

In silkworms KOYAMA (1959) reported preliminarily on the silimilar phenomenon, in which the first instar larvae previously unfed (*Nichi No. 122* and *Ō No. 18* were used) became inactive immediately after feeding. According to KOIZUMI (1954), however, the mobility of the newly hatched larvae caused by light was said to be changeless in the repletion from 6 to 12 hours and further in the shift of thermal condition from 22 to 27°C. But in the case of *Koishimaru* higher temperature clearly affected to strengthening and to disturbing the phototactic feature. The reason may due to the differences in the used materials or in the experimental methods.

Any abovedescribed facts are not attributed to the phototactic reversal caused by a light gradient. The authors, however, detected the very reverse change occurred in some varieties especially in Japanese and European varieties.

Moreover it will be noteworthy that the variety showing the one side phototaxis, positive or negative, is contained in the same race; *Ōkusa* is the variety which continues a long stability of negative phototaxis whatever light intensity may be.

Anyway phototaxis of *B. mori* is much varied among the races and among the varieties. Then what is a principal factor which caused these differences? As pointed out by KIKKAWA (1948) and MIYAGAWA & SATO (1953), the colouration of lateral ocelli of *B. mori* is closely related to phototactic behaviour; the red eyed strain exhibits higher photopositive response than the black and the white eyed strains. In case the phototactic differences in black eyed varieties may also be dependent upon qualitative differences or probably upon quantitative ones, in pigments of an ectodermal origin.

It has generally been accepted that the positive phototaxis in newly hatched larvae of phytophagous insects has an important part in their research for food. The opinion, however, is hardly applicable to those of *B. mori*, because in the Bombycid larvae some are photopositive, some are photonegative and others are changeable in phototaxis without repletion or hunger.

#### SUMMARY

In this paper an account is given of differences of phototactic responses, among the newly hatched but unfed larvae of eleven varieties of *Bombyx mori* under a light gradient (0~500 lux).

1. Phototactic signs of the larvae under the light gradient can be classified into four types;  $\oplus \rightarrow \oplus$  which means a constant positive phototaxis,  $\ominus \rightarrow \ominus$  which means a stable negative phototaxis,  $\oplus \rightarrow \ominus$  which means that a phototactic reaction reverses to negative from positive owing to the increase of light intensity, and  $\oplus \rightarrow \oplus$  which means that a phototactic sign takes not always a definite direction; under weaker illumination an initial positive phototaxis turns to the negative one, but becomes positive again under stronger illumination.

2. Japanese and European races belong to Type  $\oplus \rightarrow$  (intensified light)  $\rightarrow \ominus$  excepting *Ōkusa* belonging to an unrecorded Type  $\ominus \rightarrow$  (intensified light)  $\rightarrow \ominus$  in *B. mori*, Chinese race to Type  $\oplus \rightarrow$  (intensified light)  $\rightarrow \oplus$  with the exception of *Daizō* which shows Type  $\oplus \rightarrow$  (intensified light)  $\rightarrow \oplus$ , to which Indo-Chinese race belongs.

3. In general Japanese and European races are more active than Chinese and Indo-Chinese races either under the absence of light or under the presence of light.

4. Based mainly on phototactic characters, an opinion is proposed on mutual kinships among the varieties (Fig. 16).

5. It is concluded that the phototaxis of the newly hatched but unfed larvae of *B. mori* is so much different according to each variety that a general principle that phototaxis of phytophagous insects has a close relation to researching for food is not uniformly applicable for silkworms.

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