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盛岡高等農林學校  
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第 十 八 號

THE  
BULLETIN  
OF THE  
IMPERIAL COLLEGE OF AGRICULTURE  
AND FORESTRY

MORIOKA,  
NIPPON

No. XVIII.

Biometrical and Biological Studies of *Albugo candida* (PERS.) O. KUNTZE in Connection with its Specialization

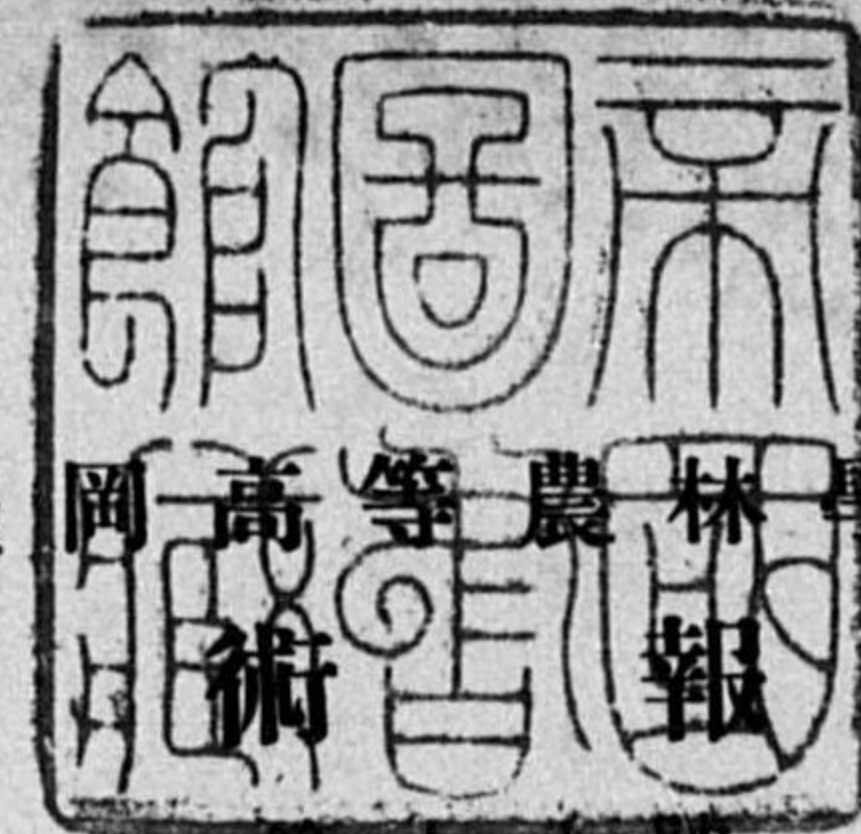
By  
KOGO TOGASHI and YOSHINOSUKE SHIBASAKI

昭和九年六月  
MORIOKA, JUNE, 1934

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Biometrical and Biological Studies of *Albugo candida* (PERS.) O. KUNTZE in Connection with its Specialization

BY

KOGO TOGASHI and YOSHINOSUKE SHIBASAKI

Introduction

It is current knowledge of plant pathology that certain parasitic fungi morphologically indistinguishable from one another show different degrees of pathogenicity due to the difference of the host plants. Thus, one so-called species of parasitic fungi sometimes contains several biologically distinct strains and furthermore even new species have been established on the basis of such specialized behavior. It is of further interest that biologic forms within a species can frequently be distinguished morphologically upon more close examination.

In Peronosporales to which the white rust fungi (species of *Albugo*) belong, specialization in this sense has also been noted by a number of investigators; viz., SAWADA (1919) and SCHWEIZER (1919) in *Bremia*, WARTENWEILER (1918) in *Plasmopara*, GÄUMANN (1918, 1926) in *Peronospora*, UPPAL and DESAI (1931) in *Sclerospora*, etc. In addition, PFISTER (1927) found several biologic forms in *Albugo Tragoponis*, and CIFFERI (1929) divided *A. Ipomoeae-panduratae* into two biologic species.

So far as *Albugo candida* is concerned, EVERHARDT (1903, 1904) was the first to make an investigation from this angle, but his experiments led him to the belief that there are probably no biologic forms in this fungus. Later, MELHUS (1911) made a series of inoculation experiments and suggested the existence of specialization in *A. candida*. Further evidence supporting MELHUS' prediction was obtained by PAPE and RABBAS (1920), whose results indicated that



the fungus on *Capsella Bursa-pastoris* should be considered a distinct form because of its parasitic nature. Thereafter, many authors of text books have taken the same affirmative view in the specialization of *A. candida* (CHUPP 1925, HEALD 1926, BROOKS 1928, ERIKSSON 1930, etc.).

The matter had then been made pretty clear, yet there still remained much to be done. Hereupon the writers started work in 1929, and a part of their morphological studies was reported the next year (TOGASHI, SHIBASAKI and KWANNO, 1930). While our study was in progress, HIURA (1930) in Japan published the results of his work on the same subject in which he distinguished three biologic forms of *Albugo candida*; the first on *Raphanus sativus*, the second on *Brassica juncea* and the third on *B. campestris* subsp. *chinensis*. To elucidate, however, a more extended investigation was required, and the work was continued.

The writers here wish to express their hearty thanks to Messrs. K. KWANNO, T. EGAMI, M. ONOGUCHI, T. KATSUKI, R. MIYAZAKI, I. YAMAGUCHI, Y. MAKI, T. HORIGOME and Y. YODOKAWA for their valuable assistance throughout the investigation.

Acknowledgements are also due for the facilities of publication given by the director, Dr. K. UYEMURA, of our College.

#### Biometrical Studies

Since the main object of the present studies lies in the determination of biologic forms within *Albugo candida*, it must be of course parasitic behavior that plays a leading part. Therefore a discussion based upon inoculation experiments will be given in the later pages of this paper. On the other hand it must be also an interesting side of the matter to ascertain whether morphologically distinct forms exist or not in this fungus that is known to be parasitic on a large number of cruciferous plants (cf. TOGASHI, SHIBASAKI, and KWANNO, 1930), because in various groups of fungi it has been proved that biologic forms exhibit comparatively remarkable morphological diversity (BLUMER 1922, LEVINE 1923, HOMMA 1929, CIFFERI

1929). Hence biometrical studies were carried out parallel with, and yet independent of, the inoculation experiments.

#### METHODS AND MATERIALS

In most cases conidia, conidiophores and oospores have been conventionally taken as the criteria for morphological comparison in a genus like *Albugo*. After a trial, however, the writers have felt that the conidium is the most suitable for the purpose. The junior author and KWANNO (1930) have already made clear that the germination-feature of conidia as well as the morphological character of zoospores is unsuitable for making comparisons among the forms of *A. candida*. Thereupon, the conidium dimensions were measured, the ratios of length to width being also calculated. Further, the products of length multiplied by width were calculated after BOUWENS (1924) in his study on Erysiphaceae.

It must be borne in mind that the sizes and shapes of certain organs of fungi are rather conspicuously variable according to their maturity, environmental conditions, etc. The most striking instances are well known in *Fusaria*, in which physiological characters are used for specific identification in place of, or supplementary to, morphological characters. Cases as just mentioned have been shown by many investigators; namely, SPURGEON (1919), LEONIAN (1926, 1929), TOGASHI (1926, 1930), HEMMI (1927), NISHIKADO (1928), NOJIMA (1929), TASUGI (1933), etc. It is thus easily supposed that the size and shape of conidia of *Albugo candida* may be greatly influenced by temperature, age and growing condition of the host plants, etc. during the course of their formation. Besides, other factors, such as the personal element, number of measurements made, etc., will play a part in causing fluctuation. Taking these factors into consideration, the materials were collected by several persons at different place and times under different environmental conditions, and eight persons in all took part in the measurement. The data thus obtained were finally brought to completion through the hands of the present writers. Such a system in morphological study seems to us adequate



to lead to a more correct conclusion and the conclusions must be reasonably admitted in the case of a fungus like *Albugo candida*, the conidium dimensions of which have been very diversely reported by the previous authors (cf. Table 30).

As to the number of conidia to measure at a time it was found that 100 are sufficient to represent a given group, and a total of 300 conidia were usually measured for each species or variety of the host plants, the conidia from fresh diseased leaves being mounted in drops of water placed on glass slides. A Leitz micrometer was used throughout the work. In the preparation of the variation tables the classes agreed in all cases with the scales of the micrometer, but the differences of each class in length and width varied according to the person. It is needless to say that the morphological comparison can be made far more easily and reasonably by the use of biometric constants than by a mere mass of individual measurements. The formulae used in the biometrical study were as follows:—

$$\text{Mean: } M = G + m \quad \text{Average deviation: } m = \frac{\sum p(A-G)}{n}$$

$$\text{Standard deviation: } \delta = \sqrt{\frac{\sum p(A-G)^2}{n} - m^2}$$

$$\text{Coefficient of variability: } C = \frac{\delta}{M} \times 100$$

$$\text{Probable error of } M: E_M = \pm 0.6745 \frac{\delta}{\sqrt{n}}$$

$$\text{Probable error of } \delta: E_\delta = \pm 0.6745 \frac{\delta}{\sqrt{2n}}$$

$$\text{Probable error of } C: E_C = \pm 0.6745 \frac{C}{\sqrt{2n}}$$

In these formulae,  $p$  represents the frequency,  $A$  the value of each variate,  $G$  the mode of the population, and  $n$  the total number of the frequency.

Curves were also plotted to show the variation in the conidium length and width. With a view to eliminating the inconveniences in comparison due to the irregularity of the class differences, the curves were prepared by representing the conidium distribution of respective classes in percentage.

Plants used in the present study belong to seven genera of the family Cruciferae, among which those of *Eutrema*, *Brassica* and *Raphanus* are vegetables cultivated widely in our country. Their scientific names as well as Japanese ones are listed as follows:—

Cruciferae	
Subfam. Sinapeae	
Sect. Alliariae	
1. <i>Eutrema Wasabi</i> MAXIM.	Wasabi
Sect. Brassicinae	
2. <i>Brassica cernua</i> FORBES et HEMSL.	Karashina
3. <i>B. chinensis</i> L.	Taisai
4.           var. <i>Komatsuna</i> MATSUM. et NAKAI	Komatsuna
5.           var. <i>oleifera</i> MAKINO	Aburana
6.           var.	Kukitachina
7. <i>B. japonica</i> SIEB.	Kyona
8.           var. <i>indivisa</i> MAKINO	Mibuna
9. <i>B. juncea</i> COSS.	Takana
10. <i>B. pekinensis</i> RUPR.	Hakusai
(1). Kekkyu-santo-hakusai	
(2). Chiifu-hakusai	
(3). Chokurei-hakusai	
(4). Hotoren-hakusai	
(5). Matsushima-hakusai	
(6). Kyoto-hakusai	
(7). Fuji-hakusai	
11. <i>B. Rapa</i> L.	Kabura
(1). Shogoin-kabu	
(2). Shiromaru-kabu	
(3). Shiromaru-kokabu	
(4). Tokinashi-kokabu	



12. *Raphanus sativus* L. var. *macropodus* MAKINO Daikon  
 f. *Horyo* MAKINO Horyo-daikon  
 f. *Miyashige* MAKINO Miyashige-daikon  
 f. *Nerima* MAKINO Nerima-daikon  
 f. *Shogoin* MAKINO Shogoin-daikon  
 Sect. Cardamininae
13. *Cardamine flexuosa* WITH. Tanetsukebana  
 Subfam. Hesperideae  
 Sect. Capsellinae
14. *Capsella Bursa-pastoris* MOENCH.  
 var. *auriculata* MAKINO Nazuna
15. *Draba nemorosa* L. var. *hebecarpa* LEDEB. Inu-nazuna  
 Sect. Turritinae
16. *Arabis hirsuta* SCOP. Yama-hatazawo

The genera here listed are arranged after PRANTL's (1891) systematic classification, and the species within a genus in alphabetical order. In the identification of the plants the writers followed MAKINO and NEMOTO (1931).

## RESULTS

I Conidia of *Albugo* on *Eutrema Wasabi*

Table 1

The results of the first two measurements on materials obtained in the glasshouse show smaller dimensions of conidium size than those of the last two obtained in nature. The difference between the mean extremities of these two groups (Measurements 1 and 4) is  $2.52 \mu$  in length and  $1.84 \mu$  in width. Yet these differences are considered to remain within the range of the variation due to environmental factors. The mean dimension in total is  $17.72 \pm 0.07 \mu$  in length and  $16.50 \pm 0.06 \mu$  in width. The extreme ranges from 13 to  $24 \mu$  in length and from 11 to  $20 \mu$  in width.

TABLE 1. Variations and constants in length and width of conidia of *Albugo* on *Eutrema Wasabi*. Measured by M. ONOGUCHI.

Measurement	Materials used		Date	Collector
	Locality			
1	Glass house, Morioka College		Aug. 19, 1931	M. ONOGUCHI
2	"		Aug. 26, 1931	"
3	Ofuke-mura, near Morioka		Aug. 31, 1931	"
4	"		Oct. 21, 1931	"

Measurement	Length in microns												Total	Mean	Standard deviation	Coefficient of variability
	13	14	15	16	17	18	19	20	21	22	23	24				
1		5	7	15	7	0	0	1					50	16.34±0.13	1.34±0.09	8.20±0.55
2	2	4	18	16	27	17	6	7	3				100	16.90±0.12	1.75±0.08	10.36±0.49
3		1	3	9	21	31	15	14	6	3	0	2	100	18.09±0.10	1.50±0.07	8.29±0.40
4				6	18	16	24	25	6				100	18.86±0.11	1.63±0.08	8.64±0.41
Total	2	10	28	46	81	71	45	46	16	3	0	2	350	17.72±0.07	1.84±0.05	10.38±0.37
%	0.6	2.9	8.0	13.2	23.2	20.3	12.9	13.2	4.9	0.9	0	0.6				

Measurement	Width in microns												Total	Mean	Standard deviation	Coefficient of variability
	11	12	13	14	15	16	17	18	19	20						
1				5	17	21	4	0	0				50	15.50±0.11	1.12±0.08	7.23±0.49
2	1	2	4	6	30	27	20	3	7				100	15.80±0.10	1.54±0.07	9.74±0.46
3			1	2	10	20	42	18	4	3			100	16.86±0.08	1.24±0.06	7.36±0.36
4				1	5	26	25	21	14	8			100	17.34±0.09	1.39±0.07	8.02±0.38
Total	1	2	7	14	62	94	91	42	25	12			350	16.50±0.06	1.54±0.04	9.33±0.24
%	0.3	0.6	2.0	4.0	17.7	26.9	26.0	12.0	7.2	3.4						



II Conidia of *Albugo candida* on *Brassica* species1) Conidia from *B. cernua*

Table 2

As shown in Table 2 the conidia measure over a range from 15.75 to 24.75  $\mu$  in length and from 15.75 to 22.5  $\mu$  in width. The mean is  $20.52 \pm 0.06 \mu$  in length and  $18.84 \pm 0.05 \mu$  in width.

2) Conidia from *B. chinensis* and its varieties

Tables 3-6; Fig. 1

More or less marked differences can be observed among the conidium dimensions of the materials from *B. chinensis* and its varieties, *Komatsuna*, *oleifera* and *Kukitachina*. In general the results obtained in 1931 (Table 3, b; Table 4, b; Table 5) show somewhat smaller dimensions in comparison with those in 1929 (Table 3, a; Table 4, a). In one extreme case of var. *Komatsuna* the difference is as large as 2.57  $\mu$  in length and 2.83  $\mu$  in width (Table 4, a, Measurement 3 and Table 4, b, Measurement 1). This may also be attributed to the fact that the material of 1931 was obtained from plants grown in the glasshouse. Figure 1 in which the curves for conidium length and width are plotted for each species and variety offers a good illustration. As shown in Tables 3-6, the conidia measure  $13-26.5 \times 10-24 \mu$  in extreme. The means are from  $21.11 \pm 0.06$  to  $18.44 \pm 0.14 \mu$  for length and from  $18.93 \pm 0.06$  to  $16.42 \pm 0.12 \mu$  for width.

3) Conidia from *B. japonica* and its varieties

Tables 7 and 8; Fig. 2

A glance at Figure 2 will show that there exists no conspicuous difference between the conidium dimensions of *B. japonica* and its variety *indivisa*.

In *B. japonica* the conidia measured in 1929 are larger than those in 1931 and 1933 with an extreme difference of 2.62  $\mu$  in length

TABLE 2. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica cernua*  
Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used															Collector	
	Locality					Date					Date						
1	College farm, Morioka					Nov. 7, 1929					Y. SHIBASAKI & K. KWANNO					"	
2	"					Nov. 9, 1929					"					"	
3	"					Nov. 15, 1929					"					"	
Total																300	
%																100	
Length in microns																	
1	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	Total	Mean	Standard deviation	Coefficient of variability
2	1	0	3	7	10	17	18	22	9	7	2	4	100	20.35 $\pm$ 0.11	1.60 $\pm$ 0.08	7.86 $\pm$ 0.37	
3	1	1	0	4	11	21	20	21	8	7	3	3	100	20.47 $\pm$ 0.10	1.48 $\pm$ 0.07	7.23 $\pm$ 0.34	
Total	1	1	4	18	30	53	51	61	34	27	10	9	300	20.52 $\pm$ 0.06	1.55 $\pm$ 0.04	7.55 $\pm$ 0.21	
%	0.4	0.4	1.8	8.0	13.3	23.6	22.7	27.1	15.1	12.0	4.4	4.0					
Width in microns																	
1	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	Total	Mean	Standard deviation	Coefficient of variability			
2	2	7	11	11	22	17	23	11	6	1	100	18.70 $\pm$ 0.09	1.29 $\pm$ 0.06	6.90 $\pm$ 0.33			
3	1	5	6	3	39	18	16	6	9	2	100	18.74 $\pm$ 0.08	1.20 $\pm$ 0.06	6.40 $\pm$ 0.31			
Total	3	14	19	88	56	63	26	24	5	2	300	19.08 $\pm$ 0.09	1.25 $\pm$ 0.06	6.55 $\pm$ 0.31			
%	1.3	6.2	8.4	39.1	24.9	28.0	11.6	10.7	2.2	0.9							



TABLE 3. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica chinensis*  
a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used															Date	Collector				
	Locality																				
1	College farm, Morioka															Oct. 22, 1929	Y. SHIBASAKI & K. KWANNO				
2	"															Oct. 24, 1929	"				
3	"															Nov. 1, 1929	"				
4	"																"				
Length in microns																					
Measurement	15	16	17	18	19	20	21	21.75	22.5	23	24	24.75	25.5	26	25	Total	Coefficient of variability				
1	0	3	2	8	5	10	18	12	13	11	5	2				100	9.85±0.47				
2			3	4	5	14	22	18	13	4	2	1				100	7.29±0.35				
3			1	4	9	15	21	16	10	7	1	0	0	1		100	7.40±0.35				
4			1	2	6	14	15	16	21	12	9	2	1	1		100	7.05±0.34				
Total	1	0	3	6	17	21	45	53	76	62	57	34	17	5	1	400	8.19±0.20				
%	0.3	0	1.0	2.0	5.7	7.0	15.0	17.7	25.3	20.7	19.0	11.3	5.7	1.7	0.3	0.7					
Width in microns																					
Measurement	14	15	15.75	16.5	17	17.25	18	18.75	19	19.5	20	20.25	21	21.75	22	22.5	23	23.25	24	Coefficient of variability	
1		8	6	16	14	24	14	8	6	4										100	8.61±0.41
2	2	1	3	9	12	16	14	22	11	7	2	1								100	8.76±0.42
3			5	14	15	16	17	14	13	5	1									100	7.53±0.36
4			3	3	11	6	22	11	17	15	8	3	1							100	8.22±0.39
Total	2	9	9	33	43	66	50	69	42	41	22	10	3	1						400	9.56±0.23
%	0.7	3.0	3.0	11.0	14.3	22.0	16.7	23.0	14.0	13.7	7.3	3.3	1.0	0.3							

b. Measured by M. ONOGUCHI

Measurement	Materials used															Date	Collector
	Locality																
1	College farm, Morioka															Oct. 31, 1931	M. ONOGUCHI
2	"															Nov. 2, 1931	"
3	"															Nov. 5, 1931	"
Length in microns																	
Measurement	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability		
1	4	6	4	11	9	30	14	8	9	3	2	100	20.14±0.15	2.26±0.11	11.35±0.54		
2	4	2	6	14	19	33	11	8	3			100	19.43±0.12	1.73±0.08	8.90±0.42		
3	1	2	6	23	12	24	20	9	3			100	19.58±0.11	1.67±0.08	8.53±0.41		
Total	9	10	16	48	40	87	45	25	15	3	2	300	19.64±0.07	1.92±0.05	9.78±0.27		
%	3.0	3.3	5.3	16.0	13.3	29.0	15.0	8.3	5.0	1.0	0.7						
Width in microns																	
Measurement	14	15	16	17	18	19	20	21	22	23	Total	Mean	Standard deviation	Coefficient of variability			
1	3	5	8	21	12	23	15	11	2		100	18.30±0.13	1.87±0.09	10.22±0.49			
2	4	3	10	29	28	9	17	3	1	2	100	17.69±0.10	1.51±0.07	8.54±0.41			
3	2	3	11	20	23	15	20	3	1	2	100	18.19±0.12	1.75±0.08	9.62±0.46			
Total	9	11	29	70	63	47	52	14	3	2	300	18.06±0.07	1.74±0.05	9.64±0.27			
%	3.0	3.7	9.7	23.3	21.0	15.7	17.3	4.7	1.0	0.7							



TABLE 4. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica chinensis* var. *Komatsuna*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement		Materials used																		Collector			
		Locality																		Date			
		College farm, Morioka																		Oct. 31, 1929		Y. SHIBASAKI & K. KWANNO	
		"																		Nov. 3, 1929		"	
		"																		Nov. 14, 1929		"	
Measurement	1	15	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	Total	Mean	Standard deviation	Coefficient of variability				
	2	1	1	0	5	5	3	17	23	25	12	7	1	3	100	20.27±0.10	1.48±0.07	7.30±0.35					
	3	2	2	6	7	12	17	27	8	5	5	5	1	3	100	20.76±0.13	1.87±0.09	9.01±0.43					
	%	5	5	7	17	13	20	14	10	6	5	1	2	100	21.01±0.11	1.69±0.08	8.05±0.38						
Total	1	1	2	7	16	17	46	53	72	34	22	12	10	2	5	300	20.68±0.07	1.72±0.05	8.32±0.23				
%	0.4	0.4	0.9	3.1	7.1	7.6	20.4	23.6	32.0	15.1	9.8	5.3	4.4	0.9	2.2								
Length in microns																							
Measurement	1	13.5	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	Total	Mean	Standard deviation	Coefficient of variability			
	2	1	0	1	1	11	17	29	16	16	3	5	100	18.19±0.09	1.30±0.06	7.15±0.34							
	3	1	4	12	20	20	25	6	9	2	1	100	18.88±0.09	1.31±0.06	6.94±0.33								
	%	5	4	24	11	20	19	10	3	2	0	1	100	19.25±0.10	1.48±0.07	7.69±0.37							
Total	1	0	1	3	20	33	73	47	61	28	24	5	3	0	1	300	18.77±0.06	1.43±0.04	7.62±0.21				
%	0.4	0	0.4	1.3	8.9	14.7	32.4	20.9	27.1	12.4	10.7	2.2	1.3	0	0.4								
Width in microns																							

b. Measured by M. ONOGUCHI

Measurement		Materials used																		Collector			
		Locality																		Date			
		Glass house, Morioka College																		June 14, 1931		M. ONOGUCHI	
Measurement	1	13	14	15	16	17	18	19	20	21	22	23	Total	Mean	Standard deviation	Coefficient of variability							
	2	2	5	4	5	9	25	16	20	8	5	1	100	18.44±0.14	2.12±0.10	11.50±0.55							
	3	18	14	15	16	17	18	19	20	21	22	23	100	18.44±0.14	2.12±0.10	11.50±0.55							
	%	2	5	4	5	9	25	16	20	8	5	1	100	18.44±0.14	2.12±0.10	11.50±0.55							
Length in microns																							
Measurement	1	10	11	12	13	14	15	16	17	18	19	20	Total	Mean	Standard deviation	Coefficient of variability							
	2	1	0	2	2	5	17	23	22	20	5	3	100	16.42±0.12	1.73±0.08	10.54±0.50							
	3	10	11	12	13	14	15	16	17	18	19	20	100	16.42±0.12	1.73±0.08	10.54±0.50							
	%	1	0	2	2	5	17	23	22	20	5	3	100	16.42±0.12	1.73±0.08	10.54±0.50							
Width in microns																							



TABLE 5. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica chinensis* var. *oleifera*

Measured by M. ONOGUCHI

Measurement	Materials used																									Collector
	Locality												Date													
1	Glass house, Morioka College												July 14, 1931												M. ONOGUCHI	
2	College farm, Morioka												Nov. 3, 1931													
3	"												Nov. 14, 1931													
Length in microns																										
Measurement	14	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability										
1	3	7	20	23	17	17	7	7	2	3	0	1	100	18.59±0.13	1.86±0.09	10.01±0.48										
2	2	5	7	17	15	19	22	6	6	6	1	1	100	19.56±0.13	1.93±0.09	9.87±0.47										
3	1	4	4	8	21	18	19	6	11	7	1	1	100	19.27±0.14	2.12±0.10	10.00±0.52										
Total	1	9	16	35	61	50	55	35	19	16	2	1	300	19.14±0.08	2.01±0.06	10.50±0.29										
%	0.3	3.0	5.3	11.7	20.3	16.7	18.3	11.7	6.3	5.3	0.7	0.3														
Width in microns																										
Measurement	13	14	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability									
1	3	1	3	36	33	18	6	3	1					100	16.01±0.08	1.15±0.05	7.18±0.34									
2	1	7	11	27	19	21	11	11	3					100	17.78±0.10	1.54±0.07	8.66±0.41									
3	3	3	3	7	26	25	13	18	2					100	17.79±0.12	1.74±0.08	9.78±0.47									
Total	3	7	46	51	71	50	37	30	5					300	17.19±0.07	1.72±0.05	10.01±0.23									
%	1.0	2.3	15.3	17.0	23.7	16.7	12.3	10.0	1.7																	

TABLE 6. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica chinensis*, Kukitachina

Measured by M. ONOGUCHI

Measurement	Materials used																									Collector
	Locality												Date													
1	College farm, Morioka												Oct. 23, 1931												M. ONOGUCHI	
2	"												Oct. 29, 1931													
3	"												Nov. 3, 1931													
Length in microns																										
Measurement	14	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability										
1	3	7	8	16	7	3	11	22	30	18	4	6	1	100	20.75±0.11	1.65±0.08	7.95±0.38									
2	3	3	3	6	11	11	10	22	17	11	6	6	1	100	19.20±0.18	2.60±0.12	13.54±0.65									
3	3	3	3	6	11	11	10	22	17	11	6	6	1	100	19.35±0.15	2.25±0.11	11.63±0.55									
Total	6	10	14	32	21	24	63	59	47	16	7	1	1	300	19.77±0.09	2.31±0.06	11.68±0.32									
%	2.0	3.3	4.7	10.7	7.0	8.0	21.0	19.7	15.7	5.3	2.3	0.3														
Width in microns																										
Measurement	13	14	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability									
1	1	5	9	20	7	12	18	24	31	11	11	1	1	100	19.05±0.09	1.33±0.06	6.98±0.33									
2	2	2	9	7	11	14	15	18	7	7	7	8	8	100	17.69±0.14	2.04±0.10	11.53±0.33									
3	3	7	18	30	34	55	55	71	26	1	1	1	1	300	18.29±0.07	1.89±0.05	10.33±0.28									
%	1.0	2.3	6.0	10.0	11.3	18.3	18.3	23.7	8.7	0.3																



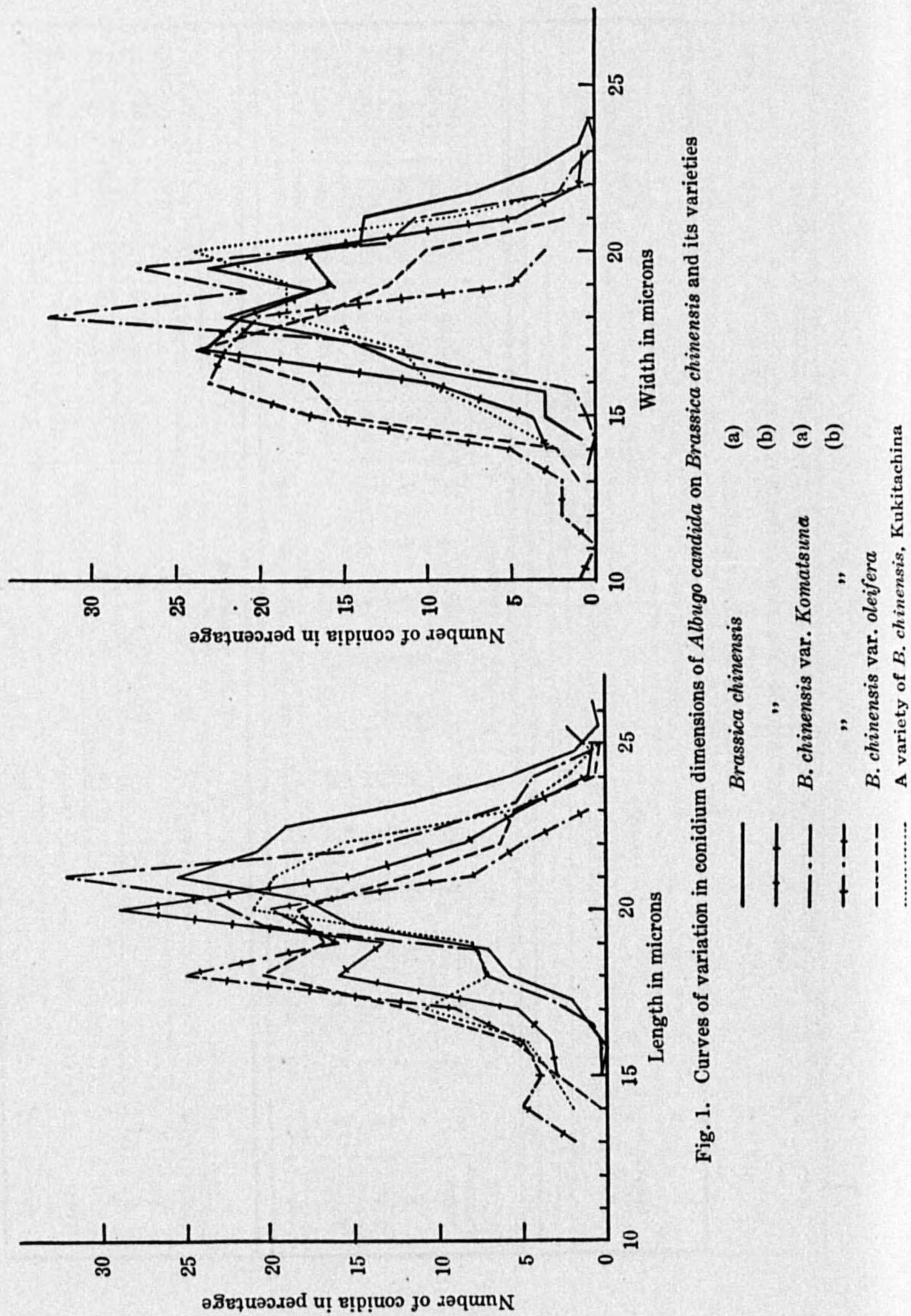


Fig. 1. Curves of variation in conidium dimensions of *Albugo candida* on *Brassica chinensis* and its varieties

TABLE 7. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica japonica*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement		Locality		Date		Collector														
1	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	26.25	27	Oct. 30, 1929	Y. SHIBASAKI & K. KWANNO		
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Nov. 8, 1929	"	
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Nov. 16, 1929	"	
Total	1	1	4	10	25	46	43	60	45	34	19	7	2	1	1	1	300			
%	0.4	0.4	1.8	4.4	11.1	20.4	19.1	26.7	20.0	15.1	8.4	3.1	0.9	0.4	0.4	0.4				
Materials used																				
Length in microns																				
Measure-ment	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	26.25	27	Total	Mean	Standard deviation	Coefficient of variability
1	2	3	8	12	13	22	14	14	9	1	1	1	1	1	1	1	100	21.01±0.11	1.61±0.08	7.66±0.37
2	1	1	6	10	19	18	12	6	4	3	1	1	1	1	1	1	100	20.44±0.11	1.64±0.08	8.02±0.38
3	1	1	1	7	15	12	20	19	14	6	3	0	0	1	1	1	100	21.15±0.11	1.61±0.08	7.61±0.37
Total	1	1	4	10	25	46	43	60	45	34	19	7	2	1	1	1	300	20.86±0.06	1.65±0.05	7.91±0.22
%	0.4	0.4	1.8	4.4	11.1	20.4	19.1	26.7	20.0	15.1	8.4	3.1	0.9	0.4	0.4	0.4				
Width in microns																				
Measure-ment	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	Total	Mean	Standard deviation	Coefficient of variability	
1	1	1	0	0	12	21	14	16	16	14	4	1	1	1	1	100	19.16±0.10	1.49±0.07	7.78±0.37	
2	2	1	8	4	30	8	34	4	4	2	2	0	1	1	1	100	18.77±0.10	1.60±0.07	7.99±0.38	
3	1	1	6	15	17	22	11	20	2	4	1	0	1	1	1	100	19.62±0.10	1.48±0.07	7.54±0.36	
Total	1	3	1	9	22	66	39	72	31	38	8	7	1	1	1	300	19.18±0.06	1.53±0.04	7.98±0.22	
%	0.4	1.3	0.4	4.0	9.8	29.3	17.3	32.0	13.8	16.9	3.6	3.1	0.4	0.4	0.4					



## b. Measured by M. ONOGUCHI

Measurement		Locality										Date			Collector
1		College farm, Morioka										Oct. 23, 1931			M. ONOGUCHI
2		"										Oct. 29, 1931			"
3		"										Oct. 31, 1931			"

Measure-ment	Length in microns																									Total	Mean	Standard deviation	Coefficient of variability
	14	15	16	17	18	19	20	21	22	23	24	25																	
1				4	16	21	31	19	4	3	1	1	100	19.80±0.10	1.48±0.07	7.47±0.36													
2	1	10	12	10	18	12	17	10	7	1	2	100	18.53±0.15	2.27±0.11	12.25±0.58														
3	3	1	7	13	13	12	18	11	13	6	3	100	19.39±0.16	2.35±0.11	12.12±0.58														
Total	4	11	19	27	47	45	66	40	24	10	6	1	300	19.24±0.08	2.14±0.06	11.12±0.31													
%	1.3	3.7	6.3	9.0	15.7	15.0	22.0	13.3	8.0	3.3	2.0	0.3																	

Measure-ment	Width in microns																									Total	Mean	Standard deviation	Coefficient of variability
	13	14	15	16	17	18	19	20	21	22	23																		
1				1	10	19	33	21	14	1	1	100	18.14±0.09	1.30±0.06	7.17±0.34														
2		5	8	19	21	13	18	13	2	1	1	100	17.51±0.12	1.81±0.09	10.34±0.49														
3	1	4	9	16	25	17	10	9	8	0	1	100	17.52±0.12	1.83±0.09	10.45±0.50														
Total	1	9	18	45	65	63	49	36	11	2	1	300	17.72±0.07	1.73±0.05	9.76±0.27														
%	0.3	3.0	6.0	15.0	21.7	21.0	16.3	12.0	3.7	0.7	0.3																		

## c. Measured by Y. YODOKAWA

Measurement		Locality										Date	Collector
1		Yamakita-machi, Ashigarakami-gun, Kanagawa Pref.										Apr. 21, 1933	Y. SHIBASAKI

Measure-ment	Length in microns																									Total	Mean	Standard deviation	Coefficient of variability
	14	15	16	17	18	19	20	21	22	23																			
1	1	1	5	6	11	14	17	28	13	3	2	100	18.92±0.13	1.89±0.09	9.99±0.48														

Measure-ment	Width in microns																									Total	Mean	Standard deviation	Coefficient of variability
	13	14	15	16	17	18	19	20	21																				
1		3	10	10	15	12	29	10	8	3	100	17.08±0.13	1.95±0.09	11.42±0.54															



TABLE 8. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica japonica* var. *indivisa*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used		Date	Collector																	
	Locality																				
1	College farm, Morioka		Nov. 1, 1929	Y. SHIBASAKI & K. KWANNO																	
2	"		Nov. 8, 1929	"																	
3	"		Nov. 15, 1929	"																	
Length in microns																					
Measurement	15	15.75	16.5	17.25	18	18.75	19.5	20	20.25	21	21.75	22.5	23	23.25	24	24.75	25.5	Total	Mean	Standard deviation	Coefficient of variability
1	1	1	2	4	10	11	13	16	22	5	5	2	2	1	100	20.19±0.13	1.96±0.09	9.71±0.46			
2	1	0	2	1	2	3	7	6	30	14	11	9	7	5	100	21.50±0.13	1.93±0.09	8.98±0.43			
3	2	1	5	8	12	19	20	13	11	6	3	100	20.71±0.11	1.61±0.08	7.77±0.37						
Total	2	1	6	6	17	22	32	41	72	32	27	20	12	7	3	300	20.80±0.07	1.91±0.05	9.18±0.25		
%	0.9	0.4	2.7	2.7	7.6	9.8	14.2	18.2	32.0	14.2	12.0	8.9	5.3	3.1	1.3						
Width in microns																					
Measurement	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	Total	Mean	Standard deviation	Coefficient of variability					
1	1	3	5	10	8	22	16	15	12	6	1	1	100	18.43±0.11	1.63±0.08	8.84±0.42					
2	1	1	0	7	3	22	37	6	8	12	3	1	100	18.91±0.09	1.38±0.07	7.30±0.35					
3	1	1	4	5	9	27	23	22	5	4	100	18.47±0.08	1.21±0.06	6.55±0.31							
Total	1	5	9	22	20	71	76	43	25	22	4	2	300	18.60±0.06	1.43±0.04	7.69±0.21					
%	0.4	2.2	4.0	9.8	8.9	31.6	33.8	19.1	11.1	9.8	1.8	0.9									

b. Measured by M. ONOBUCHI

Measurement	Materials used		Date	Collector												
	Locality															
1	College farm, Morioka		Oct. 31, 1931	M. ONOBUCHI												
2	"		Nov. 2, 1931	"												
3	"		Nov. 3, 1931	"												
Length in microns																
Measurement	14	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability
1	1	2	4	8	18	16	32	7	6	1	2	3	100	19.37±0.14	2.04±0.10	10.53±0.50
2	3	3	0	11	5	30	36	13	1	1	1	100	20.30±0.10	1.41±0.07	6.95±0.33	
3	3	7	9	24	16	23	11	4	3	100	18.94±0.12	1.79±0.09	9.45±0.45			
Total	1	5	14	17	53	37	85	54	23	5	3	3	300	19.54±0.07	1.86±0.05	9.52±0.26
%	0.3	1.7	4.7	5.7	17.7	12.3	28.3	18.0	7.7	1.7	1.0	1.0				
Width in microns																
Measurement	13	14	15	16	17	18	19	20	21	22	23	Total	Mean	Standard deviation	Coefficient of variability	
1	1	0	11	28	15	18	10	10	3	2	2	100	17.48±0.13	1.96±0.09	11.21±0.53	
2	2	2	8	4	13	16	16	35	11	2	1	100	19.05±0.11	1.58±0.08	8.29±0.40	
3	2	2	8	17	22	21	14	15	1	100	17.59±0.11	1.61±0.08	9.15±0.44			
Total	1	2	21	49	50	55	40	60	15	4	3	300	18.04±0.07	1.87±0.05	10.37±0.29	
%	0.3	0.7	7.0	16.3	16.7	18.3	13.3	20.0	5.0	1.3	1.0					



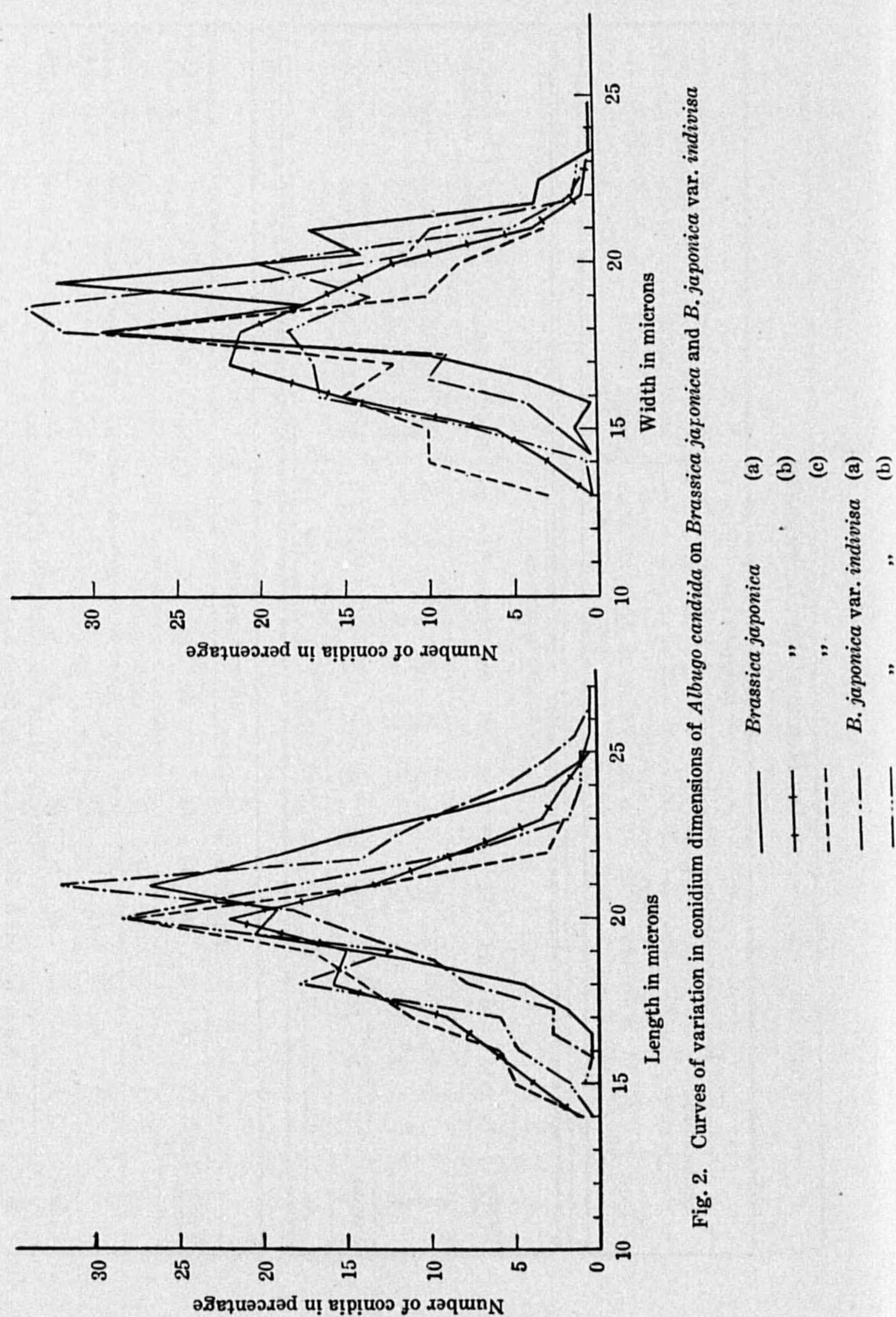


Fig. 2. Curves of variation in conidium dimensions of *Albugo candida* on *Brassica japonica* and *B. japonica* var. *indivisa*

(Table 7, a, Measurement 3 and Table 7, b, Measurement 2) and  $2.54 \mu$  in width (Table 7, a, Measurement 3 and Table 7, c, Measurement 1). The material obtained in Kanagawa Prefecture in 1933 was pretty young.

As shown in Tables 7 and 8, the conidia measure  $14-27 \times 13-24.75 \mu$  in extreme, and  $20.86 \pm 0.06-18.92 \pm 0.13 \times 19.18 \pm 0.06-17.08 \pm 0.13 \mu$  in mean.

#### 4) Conidia from *B. juncea*

Table 9

The materials used in this measurement were those sent to our laboratory in Morioka by the junior writer immediately after being collected in Kanagawa Prefecture. The measurement was made just two days after collection. As indicated in Table 9, the conidia show  $19.30 \pm 0.17 \times 16.90 \pm 0.13 \mu$  in mean.

#### 5) Conidia from various varieties of *B. pekinensis*.

Tables 10-16; Fig. 3

A number of the varieties of *B. pekinensis* were used in the present measurements. In general the conidia in 1929 show a little larger dimensions than those in 1931 and 1932. The largest difference of mean is observed in the conidia from Kekkyu-santo-hakusai; namely  $2.88 \mu$  in length (Table 10, a, Measurement 1 and Table 10, b, Measurement 1) and  $2.88 \mu$  in width (Table 10, a, Measurement 1 and Table 10, b, Measurement 1). Also in the present case it can be said that the materials collected in their earlier stage of development gave smaller dimensions of conidia. In Figure 3 attention will be naturally drawn to the graph of the Kekkyu-santo-hakusai strain which shows considerably smaller dimensions of conidia in both length and width. This measurement was made in September, one or two months earlier than the others and the host plants were also in young stage. Hence this only cannot be of significance. As shown in Tables 10-16, the conidia measure  $13-28 \times 11-26 \mu$  in extreme, and  $21.30 \pm 0.08-18.12 \pm 0.11 \times 19.56 \pm 0.07-16.37 \pm 0.08 \mu$  in mean.



TABLE 9. Variations and constants in length and width of conidia of *Albugo candida* on *Brassica juncea*.

Measured by Y. YODOKAWA

Measurement		Materials used													Collector		
		Locality											Date				
1		Yamakita-machi, Ashigarakami-gun, Kanagawa Pref.											Apr. 18, 1933		Y. SHIBASAKI		
Measure- ment	Length in microns													Total	Mean	Standard deviation	Coefficient of variability
	14	15	16	17	18	19	20	21	22	23	24	25					
1	2	5	9	10	12	12	17	13	10	5	4	1	100	19.30±0.17	2.51±0.12	13.01±0.62	
Measure- ment	Width in microns													Total	Mean	Standard deviation	Coefficient of variability
	12	13	14	15	16	17	18	19	20	21	22						
1	2	1	7	10	24	19	18	10	6	2	1	100	16.90±0.13	1.90±0.09	11.24±0.54		

TABLE 10. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Kekkyu-santo-hakusai

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement		Materials used													Collector			
		Locality											Date					
1		College farm, Morioka											Oct. 31, 1929		Y. SHIBASAKI & K. KWANNO			
2		"											Nov. 12, 1929		"			
3		"											Nov. 12, 1929		"			
Measure- ment	Length in microns													Total	Mean	Standard deviation	Coefficient of variability	
	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75						
1	4	6	7	10	15	17	14	8	9	7	3	100	21.00±0.13	1.88±0.09	8.95±0.43			
2	4	12	7	18	17	21	8	10	1	2	100	20.23±0.11	1.55±0.08	7.66±0.37				
3	3	5	9	14	17	18	7	6	3	1	100	19.94±0.11	1.63±0.08	8.12±0.39				
Total	3	13	27	28	45	50	55	29	24	13	10	3	300	20.39±0.07	1.75±0.06	8.58±0.24		
%	1.3	5.8	12.0	12.4	20.0	22.2	24.4	12.9	10.7	5.8	4.4	1.3						
Measure- ment	Width in microns													Total	Mean	Standard deviation	Coefficient of variability	
	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25					24
1	1	3	16	18	9	21	11	8	6	4	2	1	100	19.25±0.12	1.73±0.08	8.99±0.43		
2	1	2	9	14	25	7	18	15	5	2	100	18.50±0.10	1.54±0.07	8.32±0.40				
3	5	9	15	17	19	22	8	5	100	18.44±0.09	1.34±0.06	7.28±0.35						
Total	1	2	8	21	45	60	35	61	34	18	8	4	2	1	300	18.73±0.06	1.69±0.04	8.49±0.23
%	0.4	0.9	3.6	9.3	20.0	26.7	15.6	27.1	15.1	8.0	3.6	1.8	0.9	0.4				



## b. Measured by T. KATSUKI

Materials used		
Measurement	Locality	Date
1	Shitadai, Morioka	Sept. 3, 1932
		Collector
		T. KATSUKI

Measurement	Length in microns												Total	Mean	Standard deviation	Coefficient of variability
	13	14	15	16	17	18	19	20	21	22	23	24				
1	4	6	14	25	29	42	33	16	8	18	2	3	200	18.12±0.11	2.30±0.08	12.69±0.43
%	2.0	3.0	7.0	12.5	14.5	21.0	16.5	8.0	4.0	9.0	1.0	1.5				

Measurement	Width in microns												Total	Mean	Standard deviation	Coefficient of variability
	11	12	13	14	15	16	17	18	19	20	21					
1	1	3	7	9	36	51	40	39	9	4	1	200	16.37±0.08	1.65±0.06	10.08±0.34	
%	0.5	1.5	3.5	4.5	18.0	25.5	20.0	19.5	4.5	2.0	0.5					

TABLE 11. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Chiifu-hakusai  
Measured by Y. SHIBASAKI and K. KWANNO

Materials used		
Measurement	Locality	Date
1	College farm, Morioka	Nov. 2, 1929
2	"	Nov. 6, 1929
3	"	Nov. 14, 1929
		Collector
		Y. SHIBASAKI & K. KWANNO

Measurement	Length in microns												Total	Mean	Standard deviation	Coefficient of variability	
	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75					25.5
1	3	4	7	7	9	10	22	13	9	7	6	2	1	100	20.83±0.14	2.01±0.10	9.65±0.46
2	3	4	4	4	13	15	28	14	9	5	6	2	1	100	21.09±0.10	1.51±0.07	7.16±0.34
3	3	1	2	3	9	6	24	19	15	7	7	1	2	100	21.43±0.12	1.84±0.09	8.59±0.41
Total	6	5	13	14	31	31	74	46	33	19	19	5	3	300	21.16±0.07	1.81±0.05	8.55±0.24
%	2.7	2.2	5.8	6.2	13.8	13.8	32.9	20.4	14.7	8.4	2.2	1.3	0.4				

Measurement	Width in microns												Total	Mean	Standard deviation	Coefficient of variability	
	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5					23.25
1	8	5	15	18	20	11	8	6	5	1	2	0	1	100	19.46±0.12	1.82±0.09	9.35±0.45
2	3	5	26	17	24	10	11	3	1	1	1	1	1	100	19.12±0.09	1.27±0.06	6.64±0.31
3	1	0	1	5	2	10	17	21	11	20	4	5	1	100	19.70±0.11	1.74±0.08	8.83±0.42
Total	1	0	1	16	12	51	52	65	32	39	13	11	2	300	19.42±0.06	1.64±0.05	8.44±0.24
%	0.4	0	0.4	7.1	5.3	22.7	23.1	28.9	14.2	17.3	5.8	4.9	0.9				



TABLE 12. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Chokurei-hakusai

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used													Collector								
	Locality			Date			Length in microns								Standard deviation	Coefficient of variability						
1	College farm, Morioka			Nov. 1, 1929			15.75	16.5	17.25	18	18.75	19.5	20.25	21			21.75	22.5	23.25	24	24.75	25.5
2	"			Nov. 6, 1929			1	3	5	3	7	12	15	20	12	13	5	4	1.96±0.09	9.06±0.43		
3	"			Nov. 9, 1929			1	1	0	5	5	9	15	15	17	6	10	3			5	1.78±0.08
Total							1	5	5	9	14	31	35	64	39	39	19	22	8	9	1.93±0.05	
%							0.4	2.2	2.2	4.0	6.2	13.8	15.6	28.4	17.3	17.3	8.4	9.8	3.6	4.0		
Measurement	Materials used													Collector								
	Locality			Date			Width in microns								Standard deviation	Coefficient of variability						
1	College farm, Morioka			Oct. 20, 1931			15.75	16.5	17.25	18	18.75	19.5	20.25	21			21.75	22.5	23.25	24	24.75	1.97±0.09
2	"			Oct. 31, 1931			3	8	8	11	8	19	10	15	6	8	3	1	2	1.77±0.08	8.97±0.43	
3	"			Nov. 6, 1931			7	5	11	6	31	10	15	6	5	1	1	1	1			1.46±0.07
Total							3	22	16	39	26	78	30	46	16	16	4	2	2	1.76±0.05	9.00±0.25	
%							1.3	9.8	7.1	17.3	11.6	34.7	13.3	20.4	7.1	7.1	1.8	0.9	0.9			

b. Measured by Y. MAKI

Measurement	Materials used													Collector							
	Locality			Date			Length in microns								Standard deviation	Coefficient of variability					
1	College farm, Morioka			Oct. 20, 1931			15.75	16.5	17.25	18	18.75	19.5	20.25	21			21.75	22.5	23.25	24	24.75
2	"			Oct. 31, 1931			7	7	6	4	15	55	17	3	3	3	3	3	3	2.17±0.10	11.06±0.53
3	"			Nov. 6, 1931			7	3	17	12	28	10	16	4	3	16	16	16	16		
Total							2	16	29	59	137	51	6	6	6	6	6	6	6	2.27±0.06	11.78±0.32
%							0.3	2.7	4.8	9.8	22.8	8.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0		
Measurement	Materials used													Collector							
	Locality			Date			Width in microns								Standard deviation	Coefficient of variability					
1	College farm, Morioka			Oct. 20, 1931			15.75	16.5	17.25	18	18.75	19.5	20.25	21			21.75	22.5	23.25	24	24.75
2	"			Oct. 31, 1931			1	10	4	24	48	15	2	2	2	2	2	2	2	2.14±0.10	11.77±0.56
3	"			Nov. 6, 1931			1	4	4	17	47	25	5	5	5	5	5	5	5		
Total							5	18	56	139	68	12	2	2	2	2	2	2	2	2.02±0.06	11.26±0.31
%							0.8	3.0	9.3	23.2	11.3	2.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3		



TABLE 13. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Hotoren-hakusai

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used																Date	Collector		
	Locality																			
1	College farm, Morioka																Oct. 31, 1929	Y. SHIBASAKI & K. KWANNO		
2	"																Nov. 8, 1929			
3	"																Nov. 12, 1929			
Measurement	Length in microns																Total	Mean	Standard deviation	Coefficient of variability
	1	15	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	26.25				
2	1	2	3	5	7	10	11	19	13	11	10	5	2	1		100	21.14±0.14	2.04±0.10	9.65±0.46	
3	1	1	2	2	7	6	8	18	16	11	6	2	2	1	1	100	20.77±0.14	2.02±0.10	9.73±0.46	
Total	1	3	5	8	18	17	30	39	55	40	31	26	16	7	3	1	300	20.96±0.08	2.02±0.06	9.64±0.25
%	0.4	1.3	2.2	3.6	8.0	7.6	13.3	17.3	24.4	17.8	13.8	11.6	7.1	3.1	1.3	0.4				
Measurement	Width in microns																Total	Mean	Standard deviation	Coefficient of variability
	1	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24						
2	4	6	13	13	12	16	11	16	5	4						100	19.42±0.12	1.77±0.08	9.11±0.43	
3	1	4	9	11	19	11	22	13	6	1	3					100	18.72±0.11	1.59±0.08	8.49±0.40	
Total	1	9	25	31	47	29	59	33	41	11	13	0	1			300	19.10±0.07	1.74±0.05	9.11±0.25	
%	0.4	4.0	11.1	13.8	20.9	12.9	26.2	14.7	18.2	4.9	5.8	0	0.4							

b. Measured by K. MAKI

Measurement	Materials used																Date	Collector		
	Locality																			
1	Uyeda, Morioka																Oct. 31, 1931	K. MAKI		
2	"																Nov. 6, 1931			
3	"																Nov. 12, 1931			
Measurement	Length in microns																Total	Mean	Standard deviation	Coefficient of variability
	1	14	16	18	18	20	22	24								100				
2	1	9	16	16	48	20	6									100	19.19±0.14	2.05±0.10	10.30±0.49	
3	3	9	15	15	42	27	4									100	19.86±0.15	2.20±0.10	11.08±0.53	
Total	4	22	50	50	131	75	18									300	20.10±0.08	2.07±0.06	10.30±0.28	
%	0.7	3.7	8.3	8.3	21.8	12.5	3.0													
Measurement	Width in microns																Total	Mean	Standard deviation	Coefficient of variability
	1	14	16	18	18	20	22	24								100				
2	2	16	38	34	34	9	1									100	18.42±0.12	1.77±0.08	9.61±0.46	
3	6	18	44	44	29	7	6									100	18.60±0.11	1.70±0.08	9.14±0.44	
Total	10	48	112	107	107	22	1									300	18.57±0.07	1.89±0.05	10.18±0.28	
%	1.7	8.0	18.7	17.8	3.7	0.2														



TABLE 14. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Matsushima-hakusai Measured by Y. MAKI

Measurement		Materials used										Date		Collector
		Locality												
		Uyeda, Morioka										Oct. 26, 1931		Y. MAKI
		"										Nov. 6, 1931		"
		"										Nov. 12, 1931		"
Measure- ment	1	12	14	16	18	20	22	24	Total	Mean	Standard deviation	Coefficient of variability		
	2	2	4	12	28	40	12	2	100	18.88±0.16	2.30±0.10	12.18±0.58		
	3	1	6	10	26	35	19	4	100	19.26±0.16	2.38±0.11	12.36±0.59		
Total		3	17	33	84	113	42	8	300	18.76±0.16	2.31±0.11	12.31±0.59		
	%	0.5	2.6	5.5	14.0	18.8	7.0	1.3				12.34±0.31		
Measure- ment	1	12	14	16	18	20	22	24	Total	Mean	Standard deviation	Coefficient of variability		
	2	4	5	41	38	10	2	1	100	17.02±0.13	1.91±0.09	11.22±0.54		
	3	1	7	15	40	32	4	2	100	18.22±0.14	2.08±0.10	11.42±0.54		
Total		4	7	8	39	30	10	2	300	18.44±0.17	2.49±0.12	13.66±0.65		
	%	9	19	64	117	72	16	3	300	17.89±0.09	2.26±0.06	12.63±0.35		
		1.5	3.2	10.7	19.5	12.0	2.7	0.5						

TABLE 15. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Kyoto-hakusai Measured by Y. MAKI

Measurement		Materials used										Date		Collector
		Locality												
		Uyeda, Morioka										Oct. 31, 1931		Y. MAKI
		"										Nov. 6, 1931		"
		"										Nov. 12, 1931		"
Measure- ment	1	14	16	18	20	22	24	26	28	Total	Mean	Standard deviation	Coefficient of variability	
	2	2	5	17	34	24	11	5	2	100	20.72±0.18	2.74±0.14	13.22±0.63	
	3	1	8	26	36	23	4	4	1	100	19.60±0.14	2.19±0.10	11.17±0.53	
Total		6	19	62	105	71	25	9	3	300	20.52±0.17	2.54±0.12	12.38±0.59	
	%	1.0	3.2	10.3	17.5	11.9	4.2	1.5	0.5		20.28±0.28	2.55±0.07	12.57±0.35	
Measure- ment	1	14	16	18	20	22	24	26	28	Total	Mean	Standard deviation	Coefficient of variability	
	2	3	16	32	38	4	6	1	100	18.92±0.15	2.29±0.11	12.10±0.58		
	3	4	25	41	27	2	3	2	2	100	17.92±0.12	1.79±0.09	9.99±0.48	
Total		12	65	113	90	9	8	3	300	18.26±0.15	2.24±0.11	12.27±0.59		
	%	2.0	10.9	18.8	15.0	1.5	1.3	0.5		18.37±0.08	2.16±0.06	11.76±0.33		



TABLE 16. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica pekinensis*, Fuji-hakusai Measured by Y. MAKI

Measurement		Locality												Date		Collector	
		Uyeda, Morioka														Y. MAKI	
		"														"	
		"														"	
		"														"	
1	2	1	1	9	16	28	34	11	2	20.56±0.16	2.37±0.11	11.53±0.55	Oct. 31, 1931	Y. MAKI			
2	3	2	0	10	20	27	37	4	2	20.92±0.16	2.39±0.11	11.42±0.54	Nov. 2, 1931	"			
3	4	2	1	7	27	43	15	7	100	19.94±0.16	2.41±0.11	12.09±0.58	Nov. 6, 1931	"			
Total	%	3	2	29	75	130	119	38	4	400	20.03±0.08	2.37±0.06	11.33±0.27	Nov. 12, 1931	"		
		0.4	0.3	3.6	9.4	16.3	14.9	4.8	0.5								

		Length in microns															
		12	14	16	18	20	22	24	26	Total	Mean	Standard deviation	Coefficient of variability				
1	2	2	20	38	28	10	1	1	100	18.62±0.14	2.11±0.10	11.33±0.54					
3	4	1	4	21	34	34	5	1	100	19.38±0.13	1.89±0.09	9.75±0.47					
Total	%	3	7	67	152	137	31	2	400	18.60±0.07	1.95±0.05	10.48±0.25					
		0.4	0.9	8.4	19.0	17.1	3.9	0.3	0.1								

		Width in microns															
		12	14	16	18	20	22	24	26	Total	Mean	Standard deviation	Coefficient of variability				
1	2	2	20	38	28	10	1	1	100	18.62±0.14	2.11±0.10	11.33±0.54					
3	4	1	4	21	34	34	5	1	100	19.38±0.13	1.89±0.09	9.75±0.47					
Total	%	3	7	67	152	137	31	2	400	18.60±0.07	1.95±0.05	10.48±0.25					
		0.4	0.9	8.4	19.0	17.1	3.9	0.3	0.1								

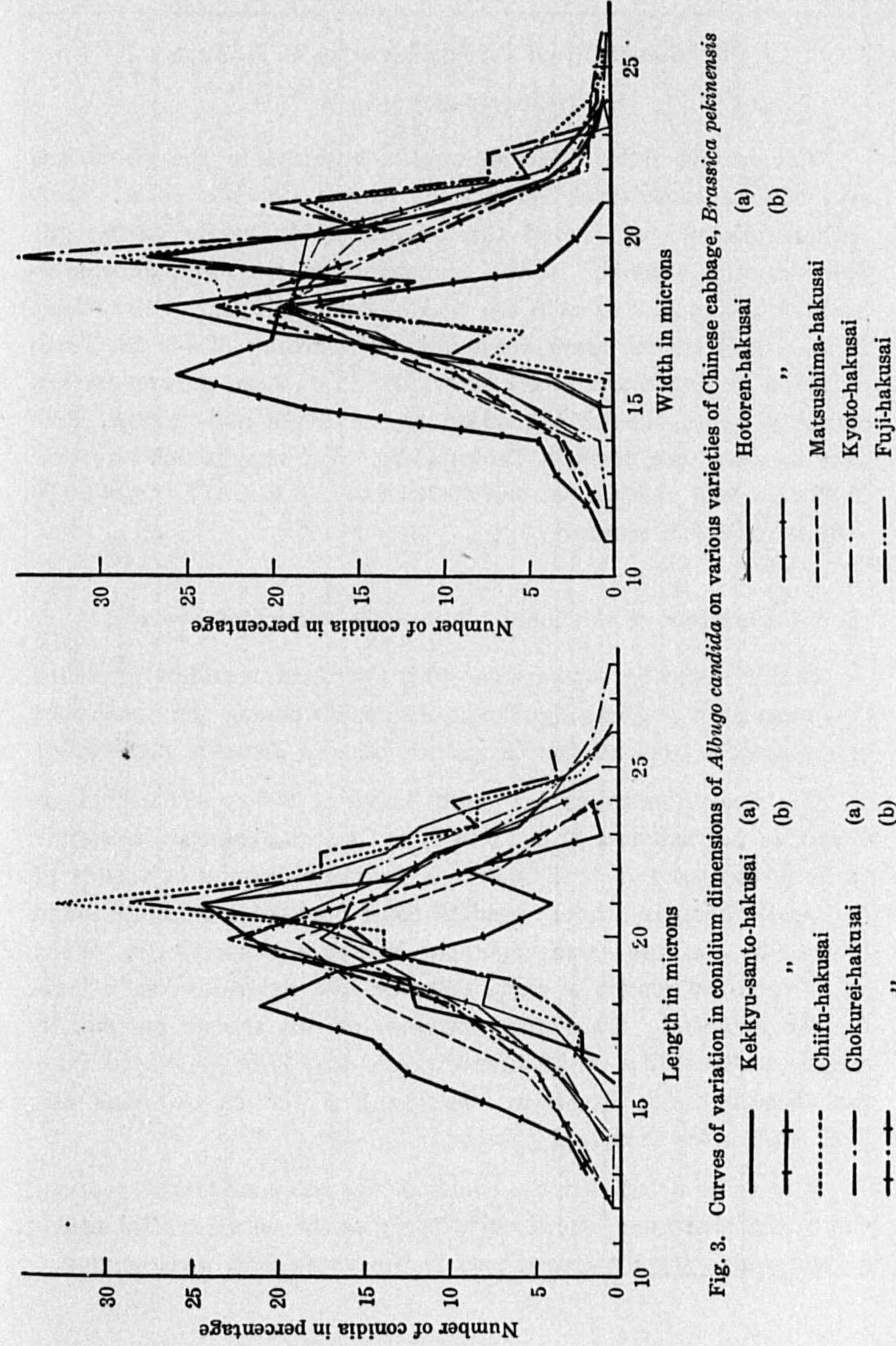


Fig. 3. Curves of variation in conidium dimensions of *Albugo candida* on various varieties of Chinese cabbage, *Brassica pekinensis*



6) Conidia from various varieties of *B. Rapa*

Tables 17-20; Fig. 4

The conidia from Tokinashi-kokabu cultured in the glasshouse are reduced considerably in size as in the previous cases. It is Shiromaru-kabu that showed the largest sized conidia among the four varieties studied. In the comparison of the mean dimensions based on 300 conidia of each the conidia from Shiromaru-kabu (Table 18, a, Total) exceed those from Tokinashi-kokabu (Table 20, Total) by  $2.58 \mu$  in length and  $2.44 \mu$  in width. Yet these differences can naturally be considered as caused by environmental factors. The data in detail are given in Tables 17-20. The conidia measure  $13-26.25 \times 11-24 \mu$  in extreme, and  $20.73 \pm 0.07-18.15 \pm 0.07 \times 18.76 \pm 0.06-16.32 \pm 0.05 \mu$  in mean.

Comparison of the conidia from each species of *Brassica*

If the preceding data are carefully examined, it will be concluded that there exist no great significant differences among the dimensions of the conidia from all species and varieties of *Brassica* studied.

The mean dimensions for length based on 300 or 400 conidia per vegetable fall between  $21.30 \pm 0.08 \mu$  in Chokurei-hakusai (a variety of *B. pekinensis*) and  $18.15 \pm 0.07 \mu$  in Tokinashi-kokabu (a variety of *B. Rapa*). Likewise, those for width come between  $19.56 \pm 0.07 \mu$  and  $16.32 \pm 0.05 \mu$  of the same vegetables as above, respectively. When based upon 100 conidia of each, however, the extremes are a little further extended. Thus the extremes of the means become, in length,  $21.66 \pm 0.12 \mu$  in Chokurei-hakusai and  $17.82 \pm 0.13 \mu$  in Tokinashi-kokabu, and, in width,  $20.20 \pm 0.11 \mu$  for *B. chinensis* and  $16.07 \pm 0.09 \mu$  for Tokinashi-kokabu.

It is to be noted that the conidium size was considerably reduced due to the particular conditions in the glass-house where Tokinashi-kokabu which plays a special part in the above data was cultured.

TABLE 17. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica Rapa*, Shogoin-kabu Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used													Collector						
	Locality			Date			Total													
1	College farm, Morioka			Oct. 21, 1929			Y. SHIBASAKI & K. KWANNO													
2	"			Oct. 26, 1929			"													
3	"			Nov. 13, 1929			"													
	Length in microns																			
Measure-ment	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	Total	Mean	Standard deviation	Coefficient of variability	
1	2	0	8	19	35	16	14	1	1	2	1	1	1	4	2	1	100	$18.23 \pm 0.09$	$1.31 \pm 0.06$	$7.18 \pm 0.34$
2				1	2	12	15	18	14	24	7	2	3	3			100	$21.50 \pm 0.10$	$1.46 \pm 0.07$	$6.79 \pm 0.32$
3			1	3	5	9	17	17	24	9	7	2	3	3			100	$20.53 \pm 0.11$	$1.67 \pm 0.08$	$8.13 \pm 0.39$
Total	2	0	9	22	41	27	43	33	43	25	32	10	7	5	1	300	$20.09 \pm 0.08$	$2.02 \pm 0.06$	$10.05 \pm 0.28$	
%	0.9	0	4.0	9.8	18.2	12.0	19.1	14.7	19.1	11.1	14.2	4.4	3.1	2.2	0.4					
	Width in microns																			
Measure-ment	13.5	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	Total	Mean	Standard deviation	Coefficient of variability			
1	1	1	3	12	19	25	23	10	2	3	1	1	6	5	100	$17.29 \pm 0.08$	$1.22 \pm 0.06$	$7.06 \pm 0.34$		
2				1	8	12	27	20	21	6	7	4	2			100	$20.02 \pm 0.08$	$1.17 \pm 0.06$	$5.84 \pm 0.28$	
3				4	18	23	11	25	6	7	4	2			100	$18.85 \pm 0.10$	$1.41 \pm 0.07$	$7.48 \pm 0.36$		
Total	1	1	3	12	23	44	54	33	54	29	29	10	7	300	$18.72 \pm 0.07$	$1.71 \pm 0.05$	$9.13 \pm 0.25$			
%	0.4	0.4	1.3	5.3	10.2	19.6	24.0	14.7	24.0	12.9	12.9	4.4	3.1							



TABLE 18. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica Rapa*, Shiromaru-kabu Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used																				Collector
	Locality										Date										
1	College farm, Morioka										Oct. 31, 1929										Y. SHIBASAKI & K. KWANNO
2	"										Nov. 6, 1929										"
3	"										Nov. 14, 1929										"
Length in microns																					
Measurement	15	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	26.25	Total	Mean	Standard deviation	Coefficient of variability		
1	2	2	5	9	13	14	16	14	12	8	4	0	0	1	100	20.82±0.12	1.82±0.09	8.74±0.42			
2	2	3	7	7	9	12	23	13	12	9	1	1	1	100	20.80±0.12	1.81±0.09	8.70±0.42				
3	1	0	0	1	8	6	21	15	19	11	10	3	4	0	1	100	20.57±0.11	1.70±0.08	8.26±0.89		
Total	1	0	4	6	20	22	43	41	58	38	34	20	9	1	2	1	300	20.73±0.07	1.78±0.05	8.59±0.24	
%	0.4	0	1.8	2.7	8.9	9.8	19.1	18.2	25.8	16.9	15.1	8.9	4.0	0.4	0.9	0.4					
Width in microns																					
Measurement	13.5	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	Total	Mean	Standard deviation	Coefficient of variability		
1	1	1	1	3	8	7	18	10	18	15	12	3	2	1	100	18.95±0.12	1.82±0.09	9.60±0.46			
2	2	2	2	8	11	20	20	24	7	6	100	18.54±0.09	1.33±0.06	7.17±0.34							
3	1	0	12	11	26	12	15	5	10	4	3	0	1	100	18.78±0.11	1.70±0.08	9.05±0.48				
Total	1	1	4	5	28	29	64	42	57	27	28	7	5	1	1	300	18.76±0.06	1.64±0.05	8.74±0.24		
%	0.4	0.4	1.8	2.2	12.4	12.9	28.4	18.7	25.3	12.0	12.4	3.1	2.2	0.4	0.4						

TABLE 19. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica Rapa*, Shiromaru-kabu Measured by M. ONOGUCHI

Measurement	Materials used																				Collector
	Locality										Date										
1	College farm, Morioka										Oct. 24, 1931										M. ONOGUCHI
2	"										Nov. 1, 1931										"
3	"										Nov. 2, 1931										"
Length in microns																					
Measurement	13	14	15	16	17	18	19	20	21	22	23	24	25	Total	Mean	Standard deviation	Coefficient of variability				
1	1	3	7	12	13	13	14	22	10	3	1	1	1	100	18.36±0.15	2.20±0.10	11.98±0.57				
2			1	6	4	25	21	22	15	5	5	1	100	21.16±0.11	1.59±0.08	7.51±0.36					
3			1	3	9	17	25	27	10	3	5			100	19.28±0.11	1.62±0.08	8.40±0.40				
Total	1	3	8	15	23	36	43	74	41	28	21	6	1	300	19.60±0.08	2.16±0.06	11.02±0.30				
%	0.3	1.0	2.7	5.0	7.7	12.0	14.3	24.7	13.7	9.3	7.0	2.0	0.3								
Width in microns																					
Measurement	11	12	13	14	15	16	17	18	19	20	21	Total	Mean	Standard deviation	Coefficient of variability						
1	1	2	0	6	10	18	19	18	14	12	12	100	17.10±0.13	1.95±0.09	11.40±0.54						
2				2	5	12	20	15	36	10	100	18.89±0.10	1.48±0.07	7.83±0.37							
3				1	11	26	24	23	18	2	100	18.04±0.09	1.31±0.06	7.26±0.35							
Total	1	2	0	6	13	34	57	62	52	61	12	300	18.01±0.07	1.76±0.05	9.77±0.27						
%	0.3	0.7	0	2.0	4.3	11.3	19.0	20.7	17.3	20.3	4.0										



TABLE 20. Variations and constants in length and width of conidia of *Albugo candida* on a variety of *Brassica Rapa*, Tokinashi-kokabu Measured by M. ONOBUCHI.

Measurement		Materials used																	Collector			
		Locality																	Date			
		Glass house, Morioka College College farm, Morioka																	July 15, 1931 Aug. 26, 1931 Oct. 1, 1931		M. ONOBUCHI " "	
		Length in microns																				
Measure-ment		13	14	15	16	17	18	19	20	21	22	23	24	Total	Mean	Standard deviation	Coefficient of variability					
1		4	4	3	9	28	28	24	8	8				100	17.85±0.08	1.20±0.06	6.72±0.33					
2		1	2	3	7	16	22	10	20	4	9	4	2	100	17.82±0.13	1.87±0.09	10.44±0.50					
3		5	6	8	25	64	70	57	43	7	9	4	2	300	18.15±0.07	1.88±0.05	10.36±0.28					
Total		1.7	2.0	2.7	8.3	21.3	23.3	19.0	14.3	2.3	3.0	1.3	0.7									
%																						
		Width in microns																				
Measure-ment		12	13	14	15	16	17	18	19	20	Total	Mean	Standard deviation	Coefficient of variability								
1		2	5	4	22	34	25	9	4	1	100	16.26±0.08	1.24±0.06	7.63±0.36								
2		2	5	1	18	35	28	11	4	5	100	16.07±0.09	1.31±0.06	8.15±0.39								
3		2	2	4	15	27	27	16	4	5	100	16.62±0.10	1.47±0.07	8.84±0.42								
Total		2	8	9	55	96	80	36	8	6	300	16.32±0.05	1.36±0.04	8.33±0.23								
%		0.7	2.7	3.0	18.3	32.0	26.7	12.0	2.7	2.0												

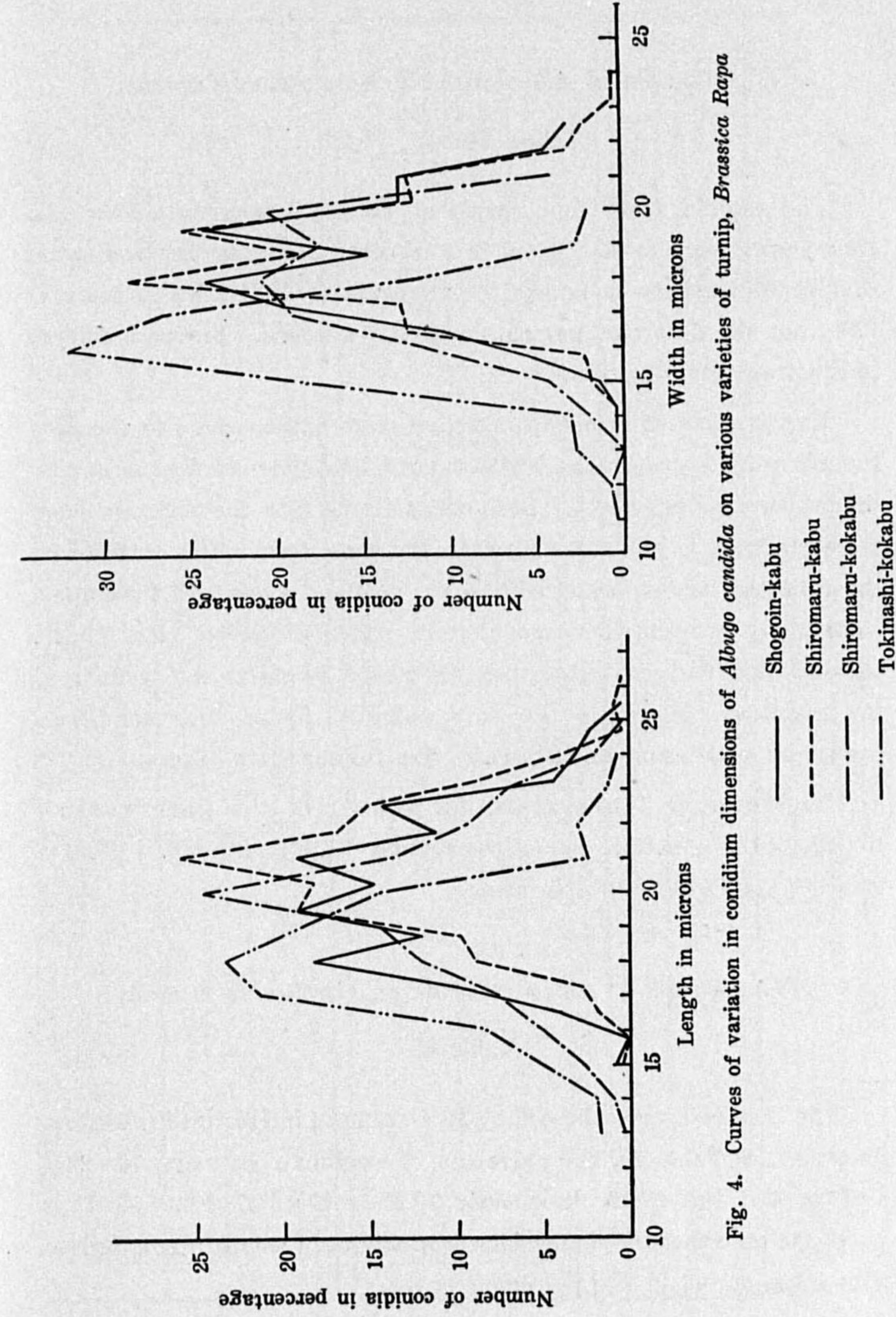


Fig. 4. Curves of variation in conidium dimensions of *Albugo candida* on various varieties of turnip, *Brassica Rapa*



III. Conidia of *Albugo candida* on *Raphanus sativus*

Tables 21-24; Fig. 5

The conidia from four forms of radish, *Raphanus sativus* var. *macropodus* were used. There is a general tendency for somewhat smaller dimensions to appear in the data of 1931 than in those of 1929, but the differences remain within 2 microns. Figure 5 suffices to illustrate the situation.

In this place it is needful to give some explanations to the data regarding f. *Shogoin* that showed considerably wide fluctuations in the measurements 2 and 3. Both materials used in the measurements were obtained at the same place in the same field. The pustules on the collected leaves looked a little too old, and almost all the conidia were easily broken when mounted in water drops on glass slides. Despite this bad condition, they were used owing to the scarcity of the material. Therefore the data obtained under such conditions cannot be a criterion to distinguish the fungus from others.

As shown in Tables 21-24, the conidia of this group measure  $15-28.5 \times 12.5-26.25 \mu$  in extreme, and  $21.92 \pm 0.12-19.54 \pm 0.07 \times 19.57 \pm 0.11-17.41 \pm 0.07 \mu$  in mean.

IV. Conidia of *Albugo candida* on *Cardamine flexuosa*

Table 25

The material was collected by M. ONOGUCHI in Ibaragi Prefecture. As shown in Table 25, the extremes of conidium size are  $10-22 \times 9-19 \mu$ , and the mean dimensions  $15.82 \pm 0.09 \times 14.12 \pm 0.07 \mu$ . It is worthy to note that the dimensions are strikingly small in comparison with those stated in the preceding pages.

TABLE 21. Variations and constants in length and width of conidia of *Albugo candida* on *Raphanus sativus* var. *macropodus* f. *Horyo*  
Measured by T. EGAMI

Measurement	Materials used										Date	Collector
	Locality											
1	College farm, Morioka										Oct. 28, 1931	T. EGAMI
2	"										Nov. 1, 1931	"
Length in microns												
	15.0	17.5	20.0	22.5	25.0	27.5	Total	Mean	Standard deviation	Coefficient of variability		
1	2	17	43	34	4	1	100	$20.53 \pm 0.17$	$2.53 \pm 0.12$	$10.32 \pm 0.59$		
2	6	14	41	36	2	1	100	$20.43 \pm 0.16$	$2.36 \pm 0.11$	$11.50 \pm 0.55$		
Total	8	31	84	70	6	1	200	$20.48 \pm 0.11$	$2.23 \pm 0.08$	$10.89 \pm 0.37$		
%	1.6	6.2	16.8	14.0	1.2	0.2						
Width in microns												
	12.5	15.0	17.5	20.0	22.5	Total	Mean	Standard deviation	Coefficient of variability			
1		11	59	30	2	100	$17.98 \pm 0.10$	$1.53 \pm 0.07$	$8.51 \pm 0.41$			
2	2	17	52	27	2	100	$17.75 \pm 0.13$	$1.92 \pm 0.09$	$10.82 \pm 0.52$			
Total	2	28	111	57	2	200	$17.86 \pm 0.08$	$1.74 \pm 0.06$	$9.74 \pm 0.33$			
%	0.4	5.6	22.2	11.4	0.4							



TABLE 22. Variations and constants in length and width of conidia of *Albugo candida* on *Raphanus sativus* var. *macropodus* f. *Miyashige*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement		Materials used															Date		Collector																														
		Locality																																															
1		College farm, Morioka															Nov. 7, 1929	Y. SHIBASAKI & K. KWANNO																															
2		"															Nov. 8, 1929	"																															
3		"															Nov. 12, 1929	"																															
Total																	300	21.02±0.08		1.95±0.05		9.28±0.26																											
%																	1.8		2.2		4.9		8.9		19.6		18.2		28.9		18.7		11.6		6.7		2.7		3.6		1.3		0.4		0		0.4		
		Length in microns																																															
Measurement		16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23	23.5	24	24.75	25.5	26.25	27	27.75	28.5	Total	Mean	Standard deviation	Coefficient of variability																										
1		3	5	13	10	20	22	8	7	1	4	5	1	0	0	1	100	21.50±0.13	1.94±0.09	9.02±0.43																													
2		1	2	4	6	15	15	25	13	10	4	3	1	1	100	20.80±0.11	1.63±0.08	7.84±0.37																															
3		3	3	4	9	16	16	20	7	8	4	2	3	2	2	1	100	20.76±0.14	2.14±0.12	10.31±0.49																													
Total		4	5	11	20	44	41	65	42	26	15	6	8	3	1	0	1	300	21.02±0.08	1.95±0.05	9.28±0.26																												
%		Width in microns																																															
Measurement		15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	Total	Mean	Standard deviation	Coefficient of variability																																	
1		1	4	5	27	24	23	9	6	1	100	18.83±0.08	1.13±0.05	6.00±0.29																																			
2		3	16	10	26	12	24	2	6	0	1	100	18.34±0.09	1.38±0.06	7.52±0.36																																		
3		1	0	8	8	30	18	9	7	1	100	18.64±0.09	1.28±0.06	6.87±0.33																																			
Total		1	4	28	23	83	54	65	20	19	2	1	300	18.60±0.05	1.28±0.04	6.88±0.19																																	
%		0.4																														1.8		10.2		36.9		24.0		28.9		8.9		8.4		0.9		0.4	

b. Measured by T. EGAMI

Measurement		Materials used															Date		Collector																				
		Locality																																					
1		College farm, Morioka															Oct. 21, 1931	T. EGAMI																					
2		"															Oct. 28, 1931	"																					
3		"															Nov. 1, 1931	"																					
Total																	300	19.54±0.07		1.91±0.05		9.77±0.27																	
%																	0.9		12.5		19.7		6.1		0.5														
		Length in microns																																					
Measurement		15.0	17.5	20.0	22.5	25.0	Total	Mean	Standard deviation	Coefficient of variability																													
1		1	30	50	18	1	100	19.70±0.12	1.85±0.09	9.39±0.45																													
2		4	36	47	11	3	100	19.35±0.14	2.05±0.10	10.59±0.51																													
3		2	30	51	17		100	19.57±0.12	1.80±0.09	9.20±0.44																													
Total		7	96	148	46	4	300	19.54±0.07	1.91±0.05	9.77±0.27																													
%		Width in microns																																					
Measurement		12.5	15.0	17.5	20.0	22.5	25.0	Total	Mean	Standard deviation	Coefficient of variability																												
1		1	16	59	24	1	100	17.75±0.11	1.64±0.08	9.24±0.44																													
2		1	17	64	16	2	100	17.68±0.11	1.68±0.08	9.58±0.46																													
3		1	18	64	18		100	17.60±0.10	1.60±0.07	8.57±0.41																													
Total		1	51	187	58	3	300	17.69±0.06	1.61±0.04	9.15±0.25																													
%		0.1																														6.8		24.9		7.7		0.4	



TABLE 23. Variations and constants in length and width of conidia of *Albugo candida* on *Raphanus sativus* var. *macropodus* f. *Nerima*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used		Date	Collector
	Locality			
1	College farm, Morioka		Oct. 23, 1929	Y. SHIBASAKI & K. KWANNO
2	"		Oct. 26, 1929	"
3	"		Oct. 31, 1929	"

Measurement	Length in microns																			Total	Mean	Standard deviation	Coefficient of variability
	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75									
1	1	1	7	9	8	12	15	23	9	9	4	1	1	100	20.26±0.12	1.78±0.08	8.79±0.42						
2			6	14	14	15	20	11	8	7	5			100	19.94±0.11	1.61±0.08	8.07±0.38						
3	1	1	4	4	11	12	13	18	11	9	3	2		100	20.05±0.13	1.89±0.09	9.43±0.46						
Total	1	2	5	17	34	33	48	52	28	25	12	3	1	300	20.08±0.07	1.77±0.05	8.81±0.24						
%	0.4	0.9	2.2	7.6	15.1	14.7	17.3	21.3	23.1	12.4	11.1	5.3	1.3	0.4									

Measurement	Width in microns																			Total	Mean	Standard deviation	Coefficient of variability
	13.5	14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25									
1	1	2	6	15	14	15	16	7	7	1	0	1	100	18.25±0.11	1.68±0.08	9.21±0.44							
2			4	5	30	18	28	6	2	1			100	17.39±0.08	1.17±0.06	6.73±0.32							
3	1	1	8	6	14	10	17	10	19	4	8	1	1	100	18.03±0.18	1.87±0.06	10.37±0.49						
Total	1	2	14	17	59	42	60	31	41	13	16	2	1	1	300	17.89±0.06	1.64±0.05	9.17±0.25					
%	0.4	0.9	6.2	7.6	26.2	18.7	26.7	13.8	18.2	5.8	7.1	0.9	0.4	0.4									

b. Measured by T. EGAMI

Measurement	Materials used		Date	Collector
	Locality			
1	College farm, Morioka		Oct. 13, 1931	T. EGAMI
2	"		Oct. 21, 1931	"
3	"		Oct. 27, 1931	"

Measurement	Length in microns										Total	Mean	Standard deviation	Coefficient of variability
	15.0	17.5	20.0	22.5	25.0									
1	2	20	36	30	12	100	20.75±0.17	2.46±0.12	11.86±0.57					
2	3	17	29	43	8	100	20.90±0.16	2.39±0.11	11.44±0.55					
3	4	23	42	27	4	100	20.10±0.15	2.26±0.11	11.24±0.54					
Total	9	60	107	100	24	300	20.58±0.09	2.40±0.07	11.66±0.32					
%	1.2	8.6	14.3	13.3	3.2									

Measurement	Width in microns										Total	Mean	Standard deviation	Coefficient of variability
	12.5	15.0	17.5	20.0	22.5									
1	9	64	25	2	100	18.00±0.10	1.54±0.07	8.56±0.41						
2	12	62	25	1	100	17.88±0.11	1.56±0.07	8.85±0.42						
3	1	17	63	17	2	100	17.55±0.11	1.69±0.08	9.63±0.46					
Total	1	38	189	67	5	300	17.81±0.06	1.61±0.04	9.04±0.25					
%	0.1	5.1	25.2	8.9	0.7									



TABLE 24. Variations and constants in length and width of conidia of *Albugo candida* on *Raphanus sativus* var. *macropodus* f. *Shogoin*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement		Locality		Date		Collector	
1	15	College farm, Morioka	Oct. 30, 1929	Y. SHIBASAKI & K. KWANNO			
2	17.25	"	Nov. 7, 1929	"			
3	19.5	"	Nov. 12, 1929	"			

Materials used		Length in microns													Coefficient of variability							
Measurement		15	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	26.25	27	27.5	28.5	Total	Mean	Standard deviation
1	2	5	12	16	13	20	11	14	6	1	6	6	16	9	11	14	15	6	7	100	19.12±0.11	1.55±0.08
2	1	0	2	1	0	1	4	1	6	6	16	9	11	14	15	6	7	100	24.98±0.16	2.44±0.12		
3	1	0	2	2	5	11	13	14	11	10	9	10	7	5					100	21.65±0.15	2.15±0.10	
Total		1	2	6	14	20	19	31	25	32	18	17	15	26	16	14	15	6	7	300	21.92±0.12	3.17±0.09
%		0.4	0.9	2.7	6.2	8.9	8.4	13.8	11.1	14.2	8.0	7.6	6.7	11.6	7.1	6.2	6.7	2.7	3.1			

Materials used		Width in microns													Coefficient of variability							
Measurement		14.25	15	15.75	16.5	17.25	18	18.75	19.5	20.25	21	21.75	22.5	23.25	24	24.75	25.5	26.25	Total	Mean	Standard deviation	
1	3	8	13	20	13	19	6	11	3	4	4	14	10	18	6	17	5	5	6	100	17.36±0.11	1.64±0.08
2	1	1	4	3	6	4	14	10	18	6	17	5	5	6					100	22.88±0.15	2.22±0.11	
3	1	1	8	12	20	13	15	9	12	5	2	0	1	1					100	19.08±0.12	1.79±0.08	
Total		3	9	14	29	26	43	22	32	16	30	15	20	6	18	6	5	6	300	19.57±0.11	2.81±0.08	
%		1.3	4.0	6.2	12.9	11.6	19.1	9.8	14.2	7.1	13.3	6.7	8.9	2.7	8.0	2.7	2.2	2.7				

b. Measured by T. EGAMI

Measurement		Locality		Date		Collector	
1	15.0	College farm, Morioka	Oct. 21, 1981	T. EGAMI			
2	17.5	"	Oct. 27, 1981	"			
3	20.0	"	Nov. 1, 1981	"			

Materials used		Length in microns													Coefficient of variability		
Measurement		15.0	17.5	20.0	22.5	25.0	27.5	Total	Mean	Standard deviation	Coefficient of variability						
1	7	35	31	26	1	1	100	19.47±0.16	2.35±0.11	12.07±0.58							
2	2	27	45	23	2	1	100	19.97±0.15	2.17±0.10	10.87±0.52							
3	9	13	56	21	1	100	19.80±0.16	2.14±0.10	10.81±0.48								
Total		18	75	132	70	4	300	19.75±0.09	2.23±0.06	11.29±0.31							
%		2.4	10.0	17.6	9.3	0.5	0.1										

Materials used		Width in microns													Coefficient of variability		
Measurement		12.5	15.0	17.5	20.0	22.5	Total	Mean	Standard deviation	Coefficient of variability							
1	1	28	51	20	100	17.25±0.12	1.78±0.08	10.32±0.49									
2	1	18	59	19	100	17.63±0.12	1.82±0.09	10.32±0.49									
3	2	29	43	25	100	17.35±0.14	2.03±0.10	11.70±0.56									
Total		4	75	153	64	4	300	17.41±0.07	1.89±0.05	10.86±0.29							
%		0.5	10.0	20.0	8.5	0.5											



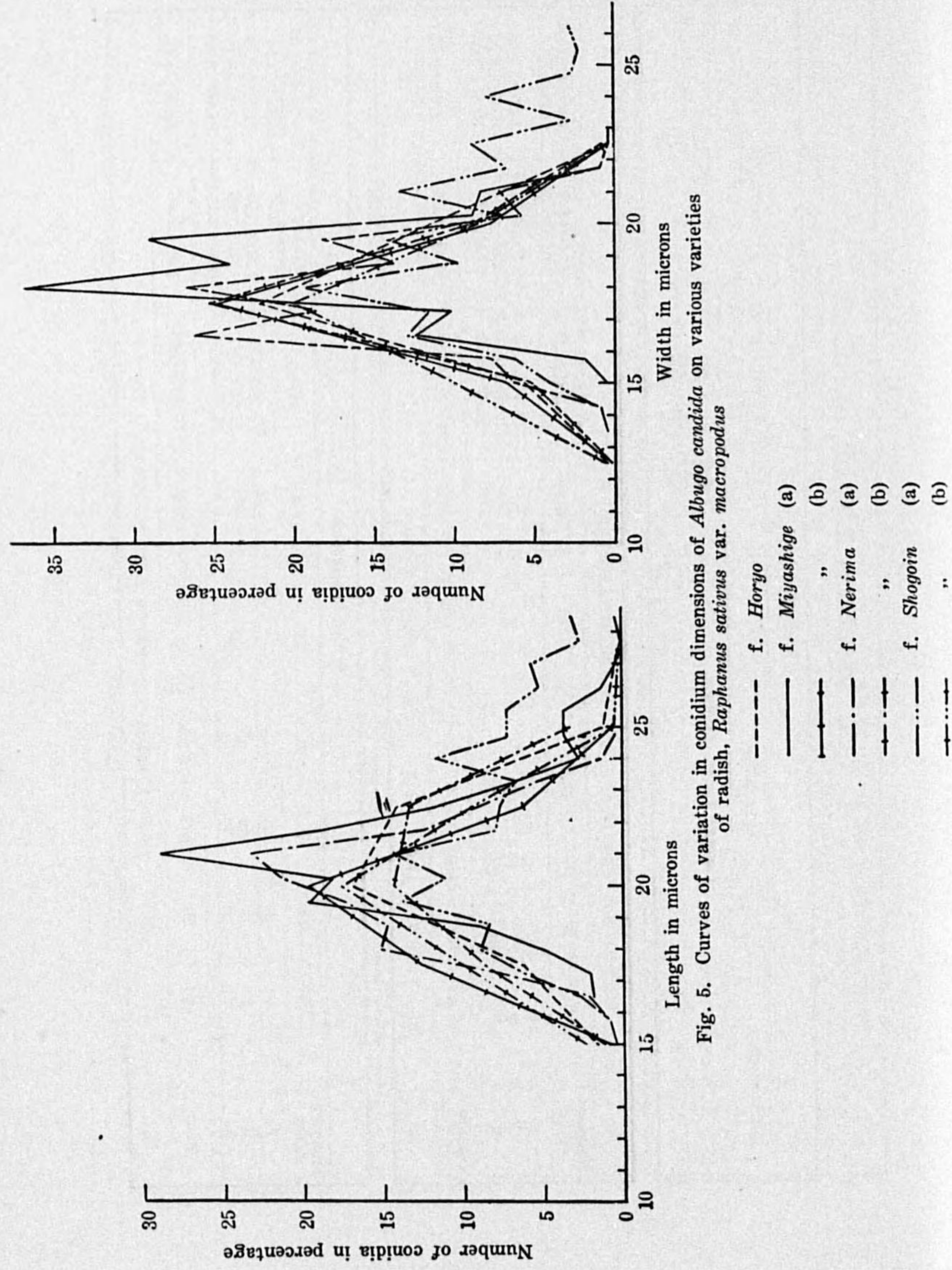


Fig. 5. Curves of variation in conidium dimensions of *Albugo candida* on various varieties of radish, *Raphanus sativus* var. *macropodus*

TABLE 25. Variations and constants in length and width of conidia of *Albugo candida* on *Cardamine flexuosa* Measured by T. KATSUKI

Measurement		Locality										Date		Collector				
1		Tamatsukuri-machi, Ibaragi Pref.										Apr. 30, 1932		M. ONOBUCHI				
		Length in microns																
Measurement		10	11	12	13	14	15	16	17	18	19	20	21	22	Total	Mean	Standard deviation	Coefficient of variability
1		3	3	12	30	42	48	56	35	31	19	13	4	4	300	15.82±0.09	2.33±0.06	14.73±0.41
%		1.0	1.0	4.0	10.0	14.0	16.0	18.7	11.7	10.3	6.3	4.3	1.3	1.3				
		Width in microns																
Measurement		9	10	11	12	13	14	15	16	17	18	19	Total	Mean	Standard deviation	Coefficient of variability		
1		2	4	8	41	42	94	42	46	11	8	2	300	14.12±0.07	1.72±0.05	12.18±0.34		
%		0.7	1.3	2.7	13.7	14.0	31.3	14.0	15.3	3.7	2.7	0.7						



TABLE 26. Variations and constants in length and width of conidia of *Albugo candida* on *Capsella Bursa-pastoris* var. *auriculata*

a. Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used																		Collector
	Locality									Date									
1	Uyeda, Morioka									June 24, 1929									Y. SHIBASAKI & K. KWANNO
2	"									June 30, 1929									"
3	"									July 6, 1929									"
4	"																		"
5	"																		"
Total	12	12.75	13.5	14.25	15	15.75	16.5	17.25	18	18.75	19.5	Total	Mean	Standard deviation	Coefficient of variability				
1	2	4	12	27	21	15	9	7	1	2	100	15.73±0.09	1.35±0.06	8.58±0.41					
2	3	4	8	25	20	15	15	6	3	1	100	15.86±0.09	1.38±0.07	8.70±0.42					
3	2	3	6	33	28	15	9	2	2		100	15.64±0.07	1.10±0.05	7.03±0.34					
4	1	3	8	21	28	17	4	1			100	15.13±0.08	1.14±0.05	7.53±0.36					
5	3	5	17	20	32	15	8				100	14.63±0.07	1.07±0.05	7.31±0.35					
Total	4	15	36	67	145	101	70	37	16	6	3	500	15.40±0.04	1.30±0.03	8.44±0.18				
%	1.1	4.0	9.6	17.9	38.7	26.9	18.7	9.9	4.3	1.6	0.8								
Length in microns																			
Measurement	Width in microns																		
	11.25	12	12.75	13.5	14.25	15	15.75	16.5	17.25	18	Total	Mean	Standard deviation	Coefficient of variability					
1	7	8	28	22	24	9	2	2	4	100	14.12±0.07	1.06±0.05	7.51±0.36						
2	3	4	18	25	31	6	7	2		100	14.68±0.08	1.25±0.06	8.52±0.41						
3	1	1	9	7	23	39	15	3	3	100	14.71±0.07	1.03±0.05	7.00±0.33						
4	1	1	5	24	22	29	9	6	3	100	14.52±0.08	1.12±0.05	7.71±0.37						
5	1	9	17	40	18	14	2			100	13.63±0.06	0.89±0.04	6.53±0.31						
Total	1	21	43	117	110	137	41	18	8	4	500	14.33±0.03	1.15±0.02	8.03±0.17					
%	0.3	5.6	11.5	31.2	29.3	36.5	10.9	4.8	2.1	1.1									

b. Measured by T. HORIGOME

Measurement	Materials used																		Collector
	Locality									Date									
1	Yamakita-machi, Ashigarakami-gun, Kanagawa Pref.									Apr. 18, 1933									Y. SHIBASAKI
Length in microns																			
Measurement	Width in microns																		
	11	12	13	14	15	16	17	18	19	20	21	Total	Mean	Standard deviation	Coefficient of variability				
1	2	6	12	12	15	20	11	7	5	8	2	100	15.73±0.16	2.39±0.11	15.19±0.72				
Width in microns																			
Measurement	Width in microns																		
	10	11	12	13	14	15	16	17	18	19	20	Total	Mean	Standard deviation	Coefficient of variability				
1	6	6	10	14	15	19	12	8	5	4	1	100	14.57±0.16	2.38±0.11	16.33±0.78				



V. Conidia of *Albugo candida* on *Capsella Bursa-pastris*  
var. *auriculata*

Table 26; Fig. 6

The conidia obtained from shepherd's purse are as small as those from *Cardamine flexuosa*. The materials obtained in the suburbs of Morioka show  $12-19.5 \times 11.25-18 \mu$  in extreme, and  $15.40 \pm 0.04 \times 14.33 \pm 0.03 \mu$  in mean, based on 500 conidia, while the materials obtained in Kanagawa Prefecture show  $11-21 \times 10-20 \mu$  in extreme, and  $15.73 \pm 0.16 \times 14.57 \pm 0.16 \mu$  in mean, based on 100 conidia. It is quite obvious that there exist no remarkable differences between the materials of these two different localities. The data are detailed in Table 26 and Figure 6.

VI. Conidia of *Albugo candida* on *Draba nemorosa*  
var. *hebecarpa*

Table 27; Fig. 6

The means of the conidium measurements obtained from this plant are  $15.08 \pm 0.08 \times 13.93 \pm 0.07 \mu$ , and the extremes  $12-21 \times 11-19 \mu$ , based on 200 conidia. Figure 6 shows the similarity in both length and width existing between the conidia from this species and those from shepherd's purse.

VII. Conidia of *Albugo candida* on *Arabis hirsuta*

Table 28; Fig. 6

The conidia from this plant measure  $11.25-18.75 \times 11.25 \times 17.25 \mu$  in extreme, and  $15.01 \pm 0.03 \times 13.90 \pm 0.03 \mu$  in mean, based on 490 conidia. Details are given in Table 28. A glance at Figure 6 will show that the conidia from *Arabis hirsuta* closely resemble those obtained from the two preceding hosts.

TABLE 27. Variations and constants in length and width of conidia of *Albugo candida*  
on *Draba nemorosa* var. *hebecarpa*  
Measured by M. ONOGUCHI

Measurement		Materials used																			Collector			
		Locality																					Date	
1		College yard, Morioka																			May 30, 1931		M. ONOGUCHI	
2		Uyeda, Morioka																			June 2, 1931			
		Length in microns																						
		12	13	14	15	16	17	18	19	20	21	Total	Mean	Standard deviation	Coefficient of variability									
1		2	4	10	18	30	16	2	1	1	100	16.05±0.11	1.63±0.08	10.16±0.48										
2		5	38	22	17	13	5	100	14.10±0.09	1.31±0.06	9.29±0.44													
Total		7	42	32	35	43	21	16	2	1	1	200	15.08±0.08	1.77±0.06	11.74±0.40									
%		3.5	21.0	16.0	17.5	21.5	10.5	8.0	1.0	0.5	0.5													
		Width in microns																						
		11	12	13	14	15	16	17	18	19	Total	Mean	Standard deviation	Coefficient of variability										
1		2	6	13	25	39	11	2	1	1	100	14.45±0.09	1.33±0.06	9.20±0.44										
2		4	18	35	25	11	7	100	13.42±0.08	1.22±0.06	9.09±0.43													
Total		6	24	48	50	50	18	2	1	1	200	13.93±0.07	1.38±0.05	9.91±0.36										
%		3.0	12.0	24.0	25.0	25.0	9.0	1.0	0.5	0.5														



TABLE 28. Variations and constants in length and width of conidia of *Albugo candida* on *Arabis hirsuta* Measured by Y. SHIBASAKI and K. KWANNO

Measurement	Materials used															Date	Collector
	Locality																
1	Uyeda, Morioka															June 24, 1929	Y. SHIBASAKI & K. KWANNO
2	"															June 26, 1929	"
3	"															June 30, 1929	"
4	"															July 4, 1929	"
5	"																"

Measurement	Length in microns															Total	Mean	Standard deviation	Coefficient of variability
	11.25	12	12.75	13.5	14.25	15	15.75	16.5	17.25	18	18.75								
1				4	18	35	23	15	3	2						100	15.33±0.06	0.94±0.04	6.13±0.29
2				4	12	36	27	9	6	5	1					100	15.51±0.07	1.07±0.05	6.90±0.33
3		2	4	16	19	24	18	5	2	2						90	14.69±0.08	1.09±0.05	7.42±0.37
4				8	27	38	11	10	3	3						100	15.07±0.07	1.02±0.05	6.77±0.32
5	1	2	7	19	27	28	12	3	0	1						100	14.42±0.07	1.07±0.05	7.42±0.35
Total	1	4	11	51	103	161	91	42	14	11	1					490	15.01±0.03	1.11±0.02	7.40±0.16
%	0.3	1.1	3.0	13.9	28.0	43.8	24.8	11.4	3.8	3.0	0.3								

Measurement	Width in microns															Total	Mean	Standard deviation	Coefficient of variability
	11.25	12	12.75	13.5	14.25	15	15.75	16.5	17.25										
1			6	35	27	24	6	2								100	14.21±0.06	0.84±0.04	5.91±0.28
2		4	26	26	29	9	3	2								100	14.45±0.07	0.97±0.05	6.71±0.32
3		17	20	31	9	8	3	1								90	13.84±0.08	1.06±0.05	7.95±0.40
4	1	6	15	43	21	12	2	1								100	13.71±0.06	0.87±0.04	6.35±0.30
5	1	4	17	36	25	15	2									100	13.75±0.06	0.87±0.04	6.33±0.30
Total	2	28	62	171	108	88	22	7	2							490	13.90±0.03	0.91±0.02	6.55±0.14
%	0.5	7.5	16.9	46.5	29.4	23.9	6.0	1.9	0.5										

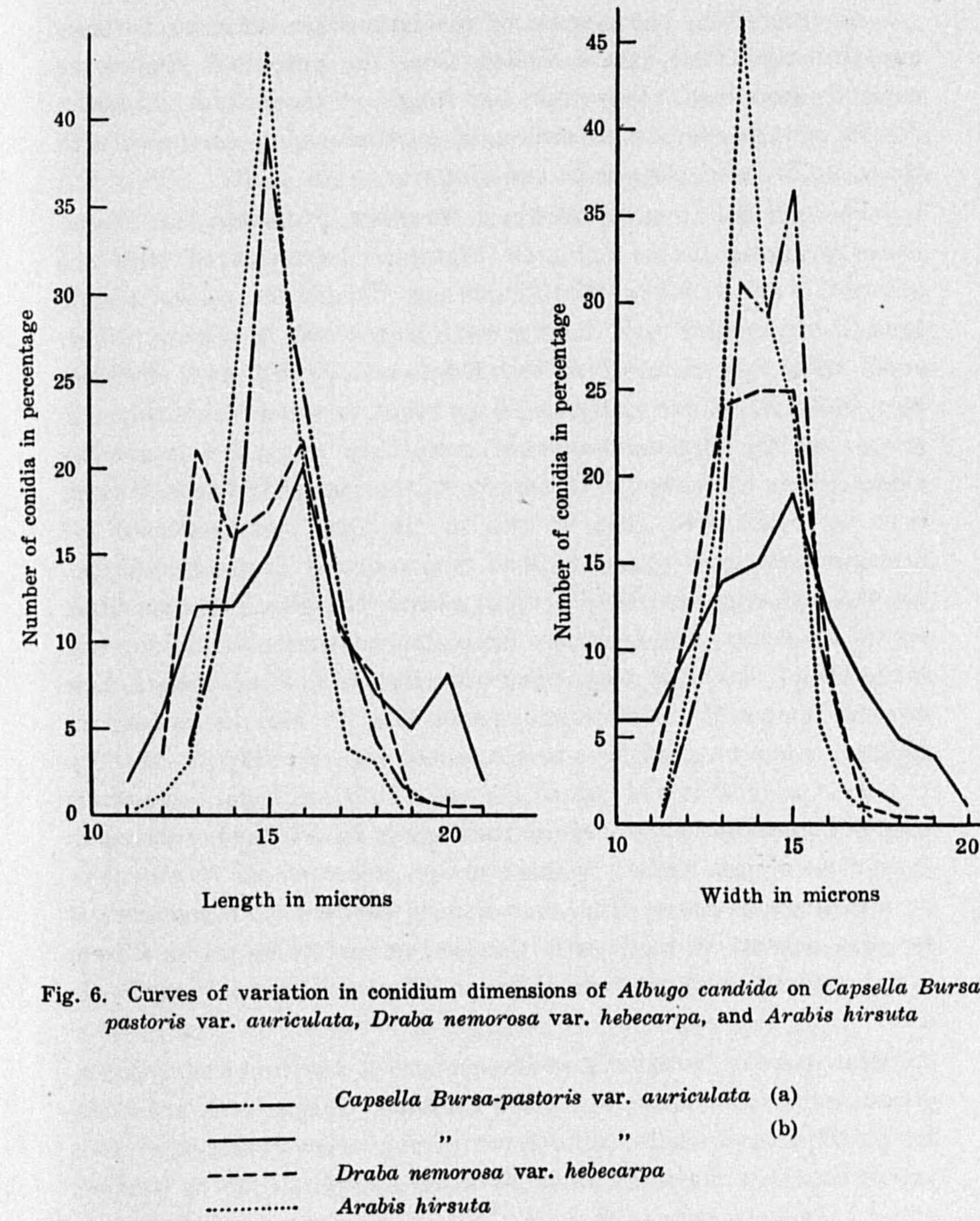


Fig. 6. Curves of variation in conidium dimensions of *Albugo candida* on *Capsella Bursa-pastoris* var. *auriculata*, *Draba nemorosa* var. *hebecarpa*, and *Arabis hirsuta*

- - - - - *Capsella Bursa-pastoris* var. *auriculata* (a)  
 - - - - - " " (b)  
 - - - - - *Draba nemorosa* var. *hebecarpa*  
 ········ *Arabis hirsuta*



## DISCUSSION

An interesting phenomenon of conidium-size-relationship becomes apparent when the data compiled from the preceding studies are carefully examined. It is that the fungi on *Cardamine*, *Capsella*, *Draba* and *Arabis* possess strikingly smaller conidia compared with those on *Brassica*, *Raphanus* and *Eutrema*.

First let the fungi on *Eutrema*, *Brassica*, *Raphanus* and *Cardamine* belonging to the subfamily Sinapeae be compared with one another. As a whole the fungus on *Cardamine* yields conidia remarkably smaller than those from *Brassica* and *Raphanus*, differences being 3-5 microns from both length and width. As is obviously seen in Table 29, the *Eutrema* group comes between the *Cardamine* group and the *Brassica-Raphanus* group. In this place, what has already been remarked with respect to the materials from *Eutrema* must be remembered, that is, two of the four materials used for measurement were obtained from plants grown in the glasshouse. As was also experienced with other plants, the glasshouse condition seems to reduce the conidium dimension to a considerable extent. HARA (1930) described the *Albugo* on *Eutrema Wasabi* as a new species naming it *A. Wasabiae*. According to him its conidia are globose, ovoid or subglobose in shape and measure  $13-22 \times 13-17 \mu$  or  $13-20 \mu$  in diameter when globose. Judging from these facts it may be appropriate to regard the fungus on *Eutrema* either as a form more or less similar to the fungi on *Brassica* and *Raphanus* or as a distinct species as HARA has already believed. At any rate it is quite natural to distinguish the fungus on *Cardamine* as a form morphologically distinct from those on *Eutrema*, *Brassica* and *Raphanus*.

Now coming to the mutual comparison of the fungi on *Capsella*, *Draba* and *Arabis* belonging to the subfamily Hesperideae, there can be found no remarkable differences among them (Table 29). It is interesting that the fungi on these three genera, so far as studied, stand extremely close to that on *Cardamine* in the conidium dimen-

sion. Even if the fungi on *Cardamine*, *Capsella*, *Draba* and *Arabis* are lumped together as one group and those on *Brassica* and *Raphanus* as another, one can find there nothing unnatural. In the former group the fluctuation of conidium dimensions pivots upon approximately 15.5 microns for length and 14.5 microns for width, while in the latter upon approximately 20 microns for length and 18 microns for width. There exists a difference of approximately 4-5 microns for both length and width of conidia between these two groups. Contrary to the ratio of length to width, the product of length multiplied by width proves a very striking difference (Table 30); the average is 364.0081 in the group with larger conidia, but 218.3900 in that with smaller ones, the ratio being 1.67. These remarkable differences are far beyond the variations caused by random sampling or other factors environmental as well as experimental, since care was specially taken in the methods and materials of the study.

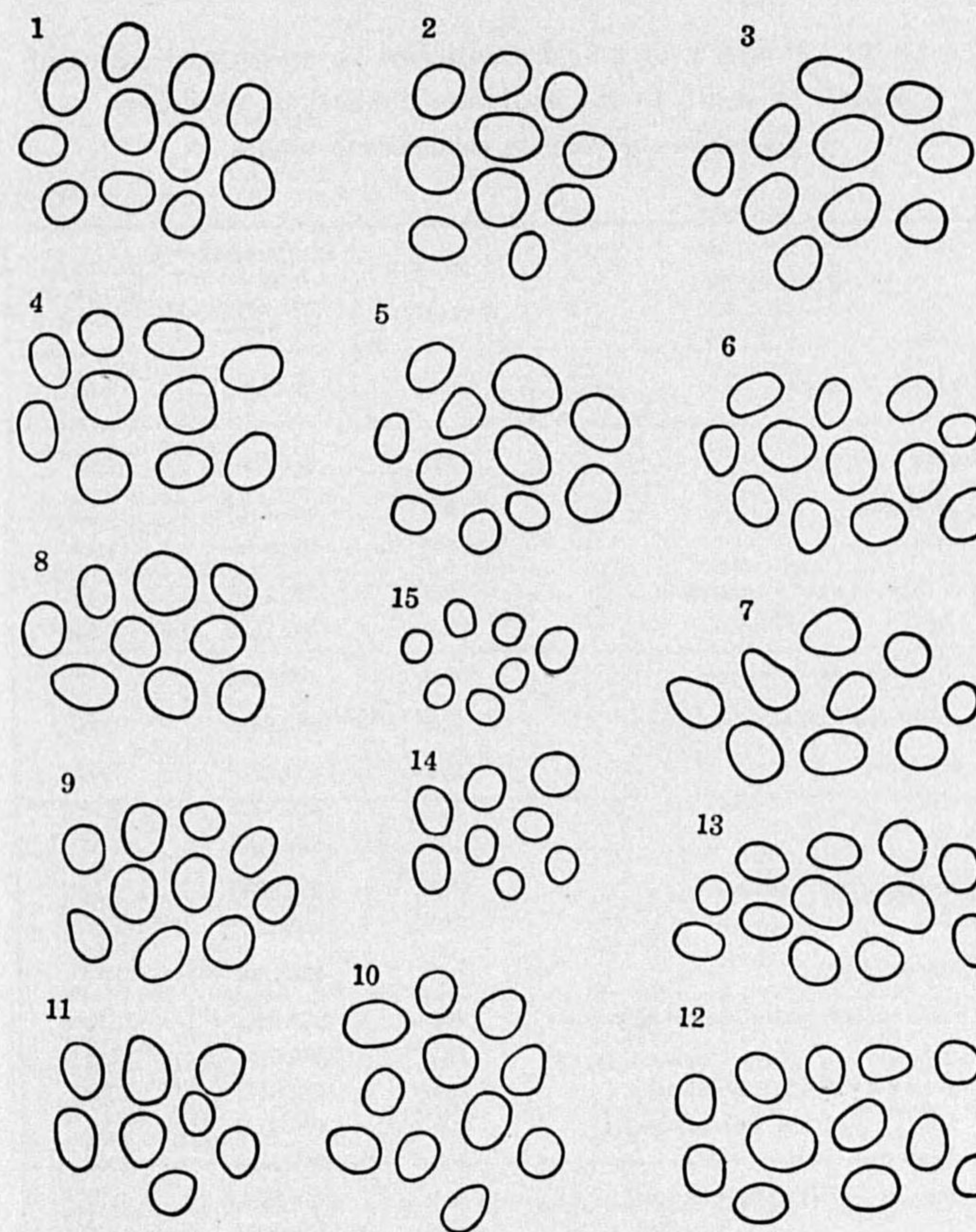
The plants of *Brassica* and *Raphanus* have long been cultivated as vegetables under environmental conditions markedly different from such wild crucifers as those of *Cardamine*, *Capsella*, *Draba* and *Arabis*. It may be supposed that they have thus acquired some distinct characters. It may also be possible that the fungi on these cultivated plants have likewise undergone a certain degree of change in morphology. So far as the field observation was concerned, it happened very often that the shepherd's purse was growing among cruciferous vegetables in the same field. In all such cases, as far as examined, the conidia produced on the former remained much smaller than those on the latter. Therefore the difference in the conidium dimensions of these two groups seems impossible to be explained from the growing conditions of the host plants.

It appears thus quite reasonable to distinguish two morphological groups within *Albugo candida*; namely, those parasitic on cruciferous weeds, such as *Cardamine*, *Capsella*, *Draba* and *Arabis*, and the other those on cultivated crucifers, such as *Brassica* and *Raphanus*.



TABLE 29. A summary of the conidium dimensions of *Albugo candida* on various cruciferous plants (in microns)

Host plants	Range		Mean		Numbers measured
	Length	Width	Length	Width	
<i>Eutrema Wasabi</i>	13-24	11-20	17.72±0.07	16.50±0.06	350
<i>Brassica</i>					
<i>cernua</i>	15.75-24.75	15.75-22.5	20.52±0.06	18.84±0.05	300
<i>chinensis</i>	15-26.25	14.25-24	21.11±0.06	18.93±0.06	400
" <i>Komatsuna</i>	15-25	14-23	19.64±0.07	18.06±0.07	300
" <i>oleifera</i>	15-25.5	13.5-24	20.68±0.07	18.77±0.06	300
" <i>Kukitachina</i>	13-23	10-20	18.44±0.14	16.42±0.12	100
" <i>japonica</i>	14-25	13-21	19.14±0.08	17.19±0.07	300
" <i>indivisa</i>	14-25	13-22	19.77±0.09	18.29±0.07	300
" <i>juncea</i>	15.75-27	14.25-24.75	20.86±0.06	19.18±0.06	300
" <i>pekinensis</i>	14-25	13-23	19.24±0.08	17.72±0.07	300
" <i>Kekkyu-santo-hakusai</i>	14-23	13-21	18.92±0.13	17.08±0.13	100
" <i>Chiifu-hakusai</i>	15-25.5	14.25-22.5	20.80±0.07	18.60±0.06	300
" <i>Chokurei-hakusai</i>	14-25	13-23	19.54±0.07	18.04±0.07	300
" <i>Hotoren-hakusai</i>	14-25	12-22	19.30±0.17	16.90±0.13	100
" <i>Matsushima-hakusai</i>	16.5-24.75	14.25-24	20.39±0.07	18.73±0.06	300
" <i>Kyoto-hakusai</i>	13-24	11-21	18.12±0.11	16.37±0.08	200
" <i>Fuji-hakusai</i>	16.5-26.25	14.25-25.5	21.16±0.07	19.42±0.06	300
" <i>Rapa</i>	15.75-25.5	15.75-24.75	21.30±0.08	19.56±0.07	300
" <i>Shogoin-kabu</i>	12-24	12-24	19.27±0.09	17.94±0.08	300
" <i>Shiromaru-kabu</i>	15-26.25	15-24	20.96±0.08	19.10±0.07	300
" <i>Shiromaru-kokabu</i>	14-24	14-24	20.10±0.08	18.57±0.07	300
" <i>Tokinashi-kokabu</i>	12-24	12-24	18.97±0.09	17.89±0.09	300
" <i>Raphanus sativus</i>	14-28	14-26	20.28±0.28	18.37±0.08	300
" <i>macropodus</i>	12-26	12-26	20.03±0.08	18.60±0.07	400
" <i>Horyo</i>	15-27.5	12.5-22.5	20.48±0.11	17.86±0.08	200
" <i>Miyashige</i>	16.5-28.5	15-22.5	21.02±0.08	18.60±0.05	300
" <i>Nerima</i>	15-25	12.5-22.5	19.54±0.07	17.69±0.06	300
" <i>Shogoin</i>	15-24.75	13.5-23.25	20.08±0.07	17.89±0.06	300
" <i>hebecarpa</i>	15-25	12.5-22.5	20.58±0.09	17.81±0.06	300
" <i>Cardamine flexuosa</i>	15-28.5	14.25-26.25	21.92±0.12	19.57±0.11	300
" <i>Capsella Bursa-pastoris</i>	15-27.5	12.5-22.5	19.75±0.09	17.41±0.07	300
" <i>auriculata</i>	10-22	9-19	15.82±0.09	14.12±0.07	300
" <i>Draba nemorosa</i>	12-19.5	11.25-18	15.40±0.04	14.33±0.03	500
" <i>hebecarpa</i>	11-21	10-20	15.73±0.16	14.57±0.16	100
" <i>Arabis hirsuta</i>	12-21	11-19	15.08±0.08	13.93±0.07	200
" <i>Arabis hirsuta</i>	11.25-18.75	11.25-17.25	15.01±0.03	13.90±0.03	490

Fig. 7. Conidia of *Albugo candida* on various plants of Cruciferae (Ca×300)

The plants from which the materials were obtained were as follows: 1-4. *Arassica pekinensis* (1. Kekkyū-santō-hakusai; 2. Hōtōren-hakusai; 3. Chiifu-hakusai; 4. Chokurei-hakusai). 5, 6. *B. Rapa* (5. Shiromaru-kabu; 6. Shōgoin-kabu). 7. *B. chinensis*. 8. *chinensis* var. *Komatsuna*. 9. *B. japonica*. 10. *B. japonica* var. *indivisa*. 11. *B. juncea*. 12, 13. *Raphanus sativus* var. *macropodus* (12. f. *Shogoin*; 13. f. *Miyashige*). 14. *Arabis hirsuta*. 15. *Capsella Bursa-pastoris* var. *auriculata*.



TABLE 30. Products of length multiplied by width and ratios of length to width in the conidium dimensions of *Albugo candida* on various cruciferous plants

Host plants	Numbers measured	Products of length multiplied by width	Ratios of length to width
<i>Eutrema Wasabi</i>	350	292.3800	1.07
<i>Brassica cernua</i>	300	386.5968	1.09
<i>B. chinensis</i>	400	399.6123	1.12
Do	300	354.6984	1.09
<i>B. chinensis</i> var. <i>Komatsuna</i>	300	388.1636	1.10
Do	100	302.7848	1.12
<i>B. chinensis</i> var. <i>oleifera</i>	300	329.0166	1.11
<i>B. chinensis</i> var. (Kukitachina)	300	361.5933	1.08
<i>B. japonica</i>	300	400.0948	1.09
Do	300	340.9328	1.09
Do	100	323.1536	1.11
<i>B. japonica</i> var. <i>indivisa</i>	300	386.8800	1.12
Do	300	352.5016	1.08
<i>B. juncea</i>	100	326.1700	1.14
<i>B. pekinensis</i> (Kekkyū-santō-hakusai)	300	381.9047	1.09
Do	200	296.6244	1.11
Do (Chiifū-hakusai)	300	410.9272	1.09
Do (Chokurei-hakusai)	300	416.6280	1.09
Do	300	345.7038	1.07
Do (Hōtōren-hakusai)	300	400.3360	1.10
Do	300	373.2570	1.08
Do (Matsushima-hakusai)	300	340.3733	1.06
Do (Kyōto-hakusai)	300	372.5436	1.10
Do (Fuji-hakusai)	400	372.5580	1.08
<i>B. Rapa</i> (Shōgoin-kabu)	300	376.0848	1.07
Do (Shiromaru-kabu)	300	388.8948	1.11
Do (Shiromaru-kokabu)	300	352.9960	1.09
Do (Tokinashi-kokabu)	300	296.2080	1.11

TABLE 30—(Continued)

Host plants	Numbers measured	Products of length multiplied by width	Ratios of length to width
<i>Raphanus sativus</i> var. <i>macropodus</i>			
f. <i>Hōryō</i>	200	365.7728	1.15
f. <i>Miyashige</i>	300	390.9720	1.13
Do	300	343.7086	1.11
f. <i>Nerima</i>	300	359.2312	1.12
Do	300	366.5298	1.16
f. <i>Shōgoin</i>	300	428.9744	1.12
Do	300	343.8475	1.13
<i>Cardamine flexuosa</i>	300	223.3784	1.12
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	500	220.6820	1.07
Do	100	229.1861	1.08
<i>Draba nemorosa</i> var. <i>hebecarpa</i>	200	210.6444	1.08
<i>Arabis hirsuta</i>	490	208.6390	1.08

TABLE 31. Sizes and shapes of conidia of *Albugo candida* given by previous authors

Authorities	Districts	Sizes	Shapes
LEVEILLE (1847)	Europe		spherical, globose
SACCARDO (1888)	do	10-18 μ	globose
SCHROETER (1889)	do	15-17	do
FISCHER (1892)	do	15-17	do
TUBEUF (1897)	do		spherical
STEVENS (1913)	America	15-18	globose
MASSE (1915)	Europe	10-16	do
BUTLER (1918)	Asia	12-18	do
HARA (1930)	do	15-20 × 15-17	ovate, elliptic, globose
IDETA (1926)	do	15-17	globose
HEALD (1926)	America	15-18	globular
BROOKS (1928)	Europe	15-18	spherical

*Albugo candida* is one of the world-wide distributed fungi and is generally considered as a collective species. The conidium size given by previous authors is as shown in Table 31.

Most recently SAVULESCU and RAYSS (1930) in Rumania divided *Albugo candida* into eight morphological forms on the basis of the dimensions of the conidia produced on various host plants. As shown in the following table, however, most of them are very similar to one another in the extremes and averages.



TABLE 32. Conidium dimensions of eight forms of *Albugo candida* erected by SAVULESCU and RAYSS

Forms	Extreme	Length in general	Length in average	Host plants
1. <i>Alyssi alyssoidis</i>	8-16	12?-15	12	<i>Alyssum</i> 1 sp.
2. <i>Brassicae nigrae</i>	9-18	11 -16	13.5	<i>Brassica</i> 1 sp.
3. <i>Capsellae Bursa-pastoris</i>	11-21	15 -19	16	<i>Capsella</i> 1 sp.
4. <i>Coronopi procumbentis</i>	11-20	14 -18	15	<i>Coronopus</i> 1 sp.
5. <i>Hesperidis matronalis</i>	11-22	14 -18	16.5	<i>Hesperis</i> 1 sp.
6. <i>Lepidii perfoliati</i>	10-19	12 -17	14.5	<i>Lepidum</i> 1 sp.
7. <i>Sinapidia arvensis</i>	11-21	12 -17	16	<i>Sinapis</i> 1 sp. <i>Syrenia</i> 1 sp. <i>Camelina</i> 2 spp. <i>Cardamine</i> 1 sp. <i>Chorispora</i> 1 sp.
8. <i>Syreniae sessiliflorae</i>	11-21	14 -19	16	<i>Erysimum</i> 1 sp. <i>Arabis</i> 2 spp. <i>Euclidium</i> 1 sp. <i>Lepidium</i> 1 sp. <i>Lunaria</i> 2 spp. <i>Raphanus</i> 1 sp. <i>Sisymbrium</i> 4 spp. <i>Thlaspi</i> 1 sp.

It is rather beyond the present authors' comprehension where they found the basis for their attempt to establish so many new forms. Nor does it seem possible to agree with their proposal.

On the other hand, the two morphological groups induced from the above data can be safely considered worthy of being treated taxonomically as varieties. And the writers suggest the establishment of two new varieties of *Albugo candida*, proposing the name var. *macrospora* for those parasitic on *Brassica* and *Raphanus*, and var. *microspora* for those on *Cardamine*, *Capsella*, *Draba* and *Arabis*.

#### Field observations

Scientific grounds for the demonstration of biologic specialization must be given by inoculation experiments. Phenomena presented in

nature, on the other hand, sometimes play a suggestive part for the question. Nature herself must sometimes be the most skilful experimenter. Hence the writers, especially through the whole year of 1931, continued search painstakingly for anything interesting about the behaviors of the white rust fungus of cruciferous plants.

It was on the shepherd's purse growing around a flower bed in the garden of our college that the writers found the fungus towards the end of April. This was for the first time in that year. About a week later, at the same place as before, the shepherd's purse was seen again severely attacked by the white rust, while among them, plants of *Cardamine flexuosa* and *Draba nemorosa* var. *hebecarpa* grew with no signs of the disease. Early in May the writers observed at a certain place in our college yard plants of the latter species very seriously affected with the white rust, while within a distance of a few feet, plants of *Arabis*, *Cardamine* as well as *Capsella* with no pustules were growing luxuriantly. Valuable suggestions will be given by these facts in nature.

In the country about Morioka damage was far more serious to *Capsella*, *Draba* and *Arabis* than to any other crucifers in the year 1931. Vegetables which are commonly seen in spring, such as pot-herb mustard (*B. japonica*), Kukitachina (a variety of *B. chinensis*) etc., so far as the writers observed, proved no occurrence of the disease. Only the varieties of turnip were found to be diseased as early as in June. Once various kinds of cruciferous vegetables were planted by the writers side by side in the garden and left to themselves, in which case only the first three of the following kinds were found to be affected with white rust: turnip (*Brassica Rapa*), Chinese cabbage (*B. pekinensis*), Komatsuna (*B. chinensis* var. *Komatsuna*), rape (*B. chinensis* var. *oleifera*), Karashina (*B. cernua*), Chinese mustard (*B. juncea*), cabbage (*B. oleracea* var. *capitata*), radish (*Raphanus sativus* var. *macropodus*) and horse-radish (*Eutrema Wasabi*).

Commonly the disease disappears in summer. Only the horse-radish is, however, most seriously diseased in this season. It seems



from this fact that the fungus on horse-radish likes higher temperatures for growth.

The disease on radish and Chinese cabbage becomes evident from September to November. In many cases healthy shepherd's purse was observed to be growing among or near the diseased radish or Chinese cabbage.

Although considerable damage was caused to the rape in the College Farm, no signs of the disease were observed on cabbage and kale which were growing very near. The writers' persistent search failed to find the disease on cabbage at any time through the whole year.

Finally the periods of the occurrence of the white rust in Morioka may be listed thus:

Host plants	Periods of occurrence
Shepherd's purse	Late April—early June, October
Draba, Arabis	May—June
Turnip	June, October—November
Potherb mustard, Mibuna, Pack-choi, Komatsuna, Kukitachina	October—November
Radish, Chinese cabbage	September—October
Horse-radish	July—August

#### Inoculation experiments

In the inoculation experiments made by EVERHARDT (1903, 1904) with the conidia from the plants of *Capsella*, *Arabis*, *Lepidium* and *Brassica*, no proof of biologic specialization within the species *Albugo candida* was observed. Afterwards, however, MELHUS (1911), with the conidia produced on radish, and PAPE and RABBAS (1920), with those on shepherd's purse, respectively made a series of inoculation experiments that led them to the recognition of the existing specialization in the same species. According to HIURA (1930), the fungus

on radish, rape and Chinese mustard respectively constitutes a distinct form in parasitic behavior. However, only two genera, *Brassica* and *Raphanus*, were concerned in his experiments as the source of inoculum.

Although the specialization in *Albugo candida* has thus been confirmed, it still remains necessary to elucidate the range by further extended experiments. Hereupon the writers carried out the following experiments in 1931 and 1932.

#### METHOD AND MATERIALS

The experiments were made from April to November in both years. Plants of the genera *Brassica* and *Raphanus* were cultured in a glasshouse of our laboratory. Young ones out of them were used for inoculation. The horse-radish, *Eutrema Wasabi*, was at first obtained in a village about 20 miles north of Morioka, and then, for the later experiments, carefully cultured in the College Farm. Cruciferous weeds, such as shepherd's purse and others, were obtained from the fields whenever needed, and used for the experiment after being proven healthy by culturing in pots. Fresh conidia as inoculum were at any time collected in the field. Conidium suspensions were prepared by dissecting pustules in distilled water with a sterilized needle. The inoculum thus prepared was applied by means of an atomizer. In a few cases, however, a writing-brush was used for the purpose instead of the atomizer. The leaves of inoculated plants were kept in moist chambers made of glass bell-jars for a few days. Careful observations were continued for more than three weeks after inoculation. Plants used in the experiments are as follows:

- |                                 |                   |        |
|---------------------------------|-------------------|--------|
|                                 | Cruciferae        |        |
|                                 | Subfam. Sinapeae  |        |
|                                 | Sect. Alliariae   |        |
| 1. <i>Eutrema Wasabi</i> MAXIM. |                   | Wasabi |
|                                 | Sect. Brassicinae |        |



2.	<i>Brassica cernua</i> FORBES. et HEMSL.	Karashina
3.	<i>B. chinensis</i> L.	Taisai
4.	var. <i>Komatsuna</i> MATSUM. et NAKAI	Komatsuna
5.	var. <i>oleifera</i> MAKINO	Aburana
6.	var.	Kukitachina
7.	<i>B. japonica</i> SIEB.	Kyona
8.	var. <i>indivisa</i> MAKINO	Mibuna
9.	<i>B. juncea</i> COSS.	Takana
10.	<i>B. oleracea</i> L.	Tamana
11.	<i>B. pekinensis</i> RUPR.	Hakusai
12.	<i>B. Rapa</i> L.	Kabura
13.	<i>Raphanus sativus</i> L. var. <i>macropodus</i> MAKINO	Daikon
	Sect. <i>Cardamininae</i>	
14.	<i>Cardamine flexuosa</i> WITH.	Tanetsukebana
	Subfam. <i>Hesperideae</i>	
	Sect. <i>Capsellinae</i>	
15.	<i>Capsella Bursa-pastoris</i> MOENCH. var. <i>auriculata</i> MAKINO	Nazuna
16.	<i>Draba nemorosa</i> L. var. <i>hebecarpa</i> LEDEB.	Inu-nazuna
	Sect. <i>Turritinae</i>	
17.	<i>Arabis hirsuta</i> SCOP.	Yama-hatazawo

## RESULTS

I. Inoculation experiments with the conidia from *Capsella Bursa-pastoris* var. *auriculata*  
(April 22, 1931; Y. MAKI)

In order to ascertain if the fungus on the shepherd's purse is biologically specialized, this experiment was first made. Besides its original host, plants of the following species were inoculated: *Eutrema Wasabi*, *Brassica japonica*, *B. japonica* var. *indivisa*, and *Draba nemorosa* var. *hebecarpa*. As shown in Table 38, the original host was very heavily infected, while infections were not obtained on others. From this result it appears that the fungus on *Capsella Bursa-pastoris* var. *auriculata* behaves as a distinct biologic form.

TABLE 33. Results of inoculation experiment with conidia from *Capsella Bursa-pastoris* var. *auriculata*

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	2 { I	++++	Very heavy	5
	Control	2 { II	++	Heavy	9
<i>Draba nemorosa</i> var. <i>hebecarpa</i>	Inoculated	2	—	—	—
	Control	3	—	—	—
<i>Brassica japonica</i>	Inoculated	2	—	—	—
	Control	3	—	—	—
<i>B. japonica</i> var. <i>indivisa</i>	Inoculated	2	—	—	—
	Control	3	—	—	—
<i>Eutrema Wasabi</i>	Inoculated	3	—	—	—
	Control	2	—	—	—

Days kept in moist chamber: 3.

II. Inoculation experiment with the conidia from *Arabis hirsuta*  
(April 27, 1931; T. EGAMI)

Plants of *Capsella Bursa-pastoris* var. *auriculata*, *Draba nemorosa* var. *hebecarpa*, *Eutrema Wasabi*, *Brassica japonica* var. *indivisa* and *Arabis hirsuta* were inoculated with conidia from *Arabis hirsuta*. Except on *Arabis hirsuta* and *Capsella Bursa-pastoris* var. *auriculata* infections were not secured (Table 34). Although a slight occurrence of the disease was observed on the shepherd's purse, it still remains doubtful whether this was caused by the employed fungus, because a few pustules were also produced on a plant for check. It was 17 days after inoculation that the pustules appeared on the shepherd's purse. The point is therefore left for further experiments. However, it must be remarked that heavy infections developed on the original host.



TABLE 34. Results of inoculation experiment with conidia from *Arabid hirsuta*

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Arabid hirsuta</i>	Inoculated	I	+++	Moderate	7
		II	++++	Heavy	12
		III	++++	Heavy	12
	Control	2	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	2 { I	+	Very slight	17
	Control	2 { II	—	Very slight	16
<i>Draba nemorosa</i> var. <i>hebecarpa</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Eutrema Wasabi</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Brassica japonica</i> var. <i>indivisa</i>	Inoculated	2	—	—	—
	Control	2	—	—	—

### III. Inoculation experiment with conidia from *Draba nemorosa* var. *hebecarpa*

(May 10, 1931; M. ONOGUCHI)

As shown in Table 35, many plants of the genera *Draba*, *Capsella*, *Arabid*, *Cardamine*, *Eutrema*, *Raphanus* and *Brassica* were used for inoculation. Only the original host, *Draba nemorosa* var. *hebecarpa*, became infected with moderate severity, while no infections occurred on the other plants. This result may show that the fungus on *Draba nemorosa* var. *hebecarpa* is biologically specialized.

### IV. Inoculation experiment with conidia from *Eutrema Wasabi*

It has been actually experienced by the writers that the white rust of horse-radish, *Eutrema Wasabi*, rages most seriously in the mid-summer through the mountain districts of Pref. Iwate. The

fungus on this plant is therefore as interesting object from the standpoint of biologic specialization.

TABLE 35. Results of inoculation experiment with conidia from *Draba nemorosa* var. *hebecarpa*

Plants		Number of plants	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Draba nemorosa</i> var. <i>hebecarpa</i>	Inoculated	2	+++	Moderate	10
	Control	2	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Arabid hirsuta</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Cardamine flexuosa</i>	Inoculated	1	—	—	—
	Control	2	—	—	—
<i>Eutrema Wasabi</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Shogoin)	Inoculated	1	—	—	—
	Control	2	—	—	—
<i>Brassica pekinensis</i> (Chokurei-hakusai)	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>B. juncea</i>	Inoculated	1	—	—	—
	Control	2	—	—	—
<i>B. chinensis</i> var. <i>Komatsuna</i>	Inoculated	1	—	—	—
	Control	2	—	—	—

Days kept in moist chamber: 3.

### Experiment 1

(Aug. 31, 1931; T. EGAMI)

In addition to the horse-radish, plants of *Brassica pekinensis* and *Raphanus sativus* var. *macropodus* were used in the present experiment. The result is given in Table 36, according to which a heavy infection was obtained on the original host. However, the other plants were not infected.



## Experiment 2

(Nov. 16, 1931: T. EGAMI)

Plants of *Eutrema Wasabi*, *Brassica pekinensis*, *Raphanus sativus* var. *macropodus* and *Capsella Bursa-pastoris* var. *auriculata* were used in this experiment. The result was wholly negative. This may perhaps be attributed to the coldness in this season.

TABLE 36. Results of inoculation experiment with conidia from *Eutrema Wasabi*

Plants		Number of pots	Results		Incubation period (days)	
			Pustules	Degree of infection		
<i>Eutrema Wasabi</i>	Inoculated	3	I	++	Slight	6
			II	++++	Heavy	7
			III	++++	Heavy	7
	Control	3	—	—	—	
<i>Brassica pekinensis</i> (Fuji-hakusai)	Inoculated	3	—	—	—	
	Control	2	—	—	—	
Do (Matsushima-hakusai)	Inoculated	3	—	—	—	
	Control	2	—	—	—	
<i>Raphanus sativus</i> var. <i>macropodus</i> (Nerima)	Inoculated	3	—	—	—	
	Control	2	—	—	—	

Days kept in moist chamber: 2.

V. Inoculation experiments with conidia from *Brassica cernua*

## Experiment 1

(Nov. 2, 1932; T. KATSUKI, R. MIYAZAKI and I. YAMAGUCHI)

Plants inoculated were those of the following species: *Brassica japonica* var. *indivisa*, *B. pekinensis*, *B. Rapa*, *B. cernua*, *B. chinensis*, *B. japonica*, *Raphanus sativus* var. *macropodus*, *Arabis hirsuta* and *Capsella Bursa-pastoris* var. *auriculata*.

The first three of the above mentioned species were infected with different degrees of severity, while the others gave no signs of

infection (Table 37). It is curious that infection did not occur on the original host, *Brassica cernua*. It is likely that the leaves of *B. cernua* would not retain the drops of suspension, although it was applied with a writing-brush, owing to their hairy surface.

## Experiment 2

(Nov. 18, 1932; T. KATSUKI, R. MIYAZAKI and I. YAMAGUCHI)

Plants inoculated are shown in Table 38. Conidium suspensions were carefully applied by means of a writing-brush. The result was that the original host, *Brassica cernua*, became very slightly infected, while on the others no infections were secured. It seemed to us that the result was influenced by the cold weather of this season.

TABLE 37. Results of inoculation experiment with conidia from *Brassica cernua* (1)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica cernua</i>	Inoculated	2	—	—	—
	Control	1	—	—	—
<i>B. japonica</i> var. <i>indivisa</i>	Inoculated	2	+++	Moderate	6
	Control	1	—	—	—
<i>B. pekinensis</i>	Inoculated	1	+	Slight	7
	Control	1	—	—	—
<i>B. Rapa</i> (Tennoji-kabu)	Inoculated	2	++++	Heavy	6
	Control	1	—	—	—
<i>B. chinensis</i>	Inoculated	2	—	—	—
	Control	1	—	—	—
<i>B. japonica</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Shogoin)	Inoculated	2	—	—	—
	Control	1	—	—	—
<i>Arabis hirsuta</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber: 2.



TABLE 38. Results of inoculation experiment with conidia from *Brassica cernua* (2)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica cernua</i>	Inoculated	2	+	Very slight	19
	Control	1	—	—	—
<i>B. chinensis</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. japonica</i> var. <i>indivisa</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. Rapa</i> (Benimaru-kabu)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Shōgoin)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Arabis hirsuta</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber: 3.

TABLE 39. Results of inoculation experiment with conidia from *Brassica chinensis*

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica chinensis</i>	Inoculated	2	+++	Moderate	8
	Control	1	—	—	—
<i>B. japonica</i> var. <i>indivisa</i>	Inoculated	1	+	Slight	12
	Control	1	—	—	—
<i>B. pekinensis</i> (Chiifū-Hakusai)	Inoculated	1	++++	Heavy	4
	Control	1	—	—	—
<i>B. cernua</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. japonica</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. oleracea</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Shōgoin)	Inoculated	2	—	—	—
	Control	1	—	—	—
<i>Arabis hirsuta</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber: 2.

VI. Inoculation experiment with conidia from *Brassica chinensis* (Nov. 10, 1932; T. KATSUKI, R. MIYAZAKI and I. YAMAGUCHI)

The following plants were inoculated: *Brassica chinensis*, *B. japonica* var. *indivisa*, *B. pekinensis*, *B. cernua*, *B. japonica*, *B. oleracea*, *Raphanus sativus* var. *macropodus*, *Arabis hirsuta* and *Capsella Bursa-pastoris* var. *auriculata*. Among these, the first three species were infected with different degrees of severity (Table 39). On the other species, however, no trace of infection occurred.

VII. Inoculation experiments with conidia from *Brassica pekinensis*

## Experiment 1

(Oct. 31, 1931; Y. MAKI)

Inoculations were made on plants of *Brassica pekinensis*, a variety of *B. chinensis*, *Kukitachina*, *Raphanus sativus* var. *macropodus* and *Capsella Bursa-pastoris* var. *auriculata*. As shown in Table 40, *Brassica pekinensis* only became heavily or moderately infected. The other plants remained uninfected.

## Experiment 2

(Nov. 3, 1931; Y. MAKI)

Much the same experiment as above was repeated. This time, however, *Brassica Rapa* was added. The data are given in Table 41, where one may see that *B. Rapa* was also infected besides the original host, *B. pekinensis*.

## Experiment 3

(Oct. 13, 1932; T. KATSUKI, R. MIYAZAKI and I. YAMAGUCHI)

Plants of various other species were used in this experiment; namely *B. japonica*, *B. japonica* var. *indivisa*, *B. cernua* and *B. oleracea*. Infections were secured on *B. pekinensis*, *B. japonica*, *B. japonica* var. *indivisa* and *B. Rapa*. The infection was heavy except on *B. japonica*. The data are given in Table 42.



TABLE 40. Results of inoculation experiment with conidia from *Brassica pekinensis* (Matsushima-hakusai)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica pekinensis</i> (Matsushima-Hakusai)	Inoculated	1	++++	Heavy	9
	Control	1	—	—	—
Do (Fuji-Hakusai)	Inoculated	1	+++	Moderate	7
	Control	1	—	—	—
Do (Chokurei-Hakusai)	Inoculated	1	+++	Moderate	9
	Control	1	—	—	—
<i>B. chinensis</i> var. (Kukitachina)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Nerima)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i> .	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber : 4.

TABLE 41. Results of inoculation experiment with conidia from *Brassica pekinensis* (Hötören-hakusai)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica pekinensis</i> (Chokurei-Hakusai)	Inoculated	1	++++	Heavy	8
	Control	1	++	—	—
<i>B. Rapa</i> (Tokinashi-Kokabu)	Inoculated	1	+++	Moderate	9
	Control	1	—	—	—
<i>B. chinensis</i> var. (Kukitachina)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Shōgojin)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber : 5.

TABLE 42. Results of inoculation experiment with conidia from *Brassica pekinensis* (Chiifū-hakusai)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica pekinensis</i> (Chiifū-Hakusai)	Inoculated	2	++++	Heavy	21
	Control	2	—	—	—
<i>B. japonica</i>	Inoculated	2	++++	Heavy	13
	Control	2	—	—	—
<i>B. japonica</i> var. <i>indivisa</i>	Inoculated	2	++	Moderate	12
	Control	2	—	—	—
<i>B. Rapa</i> (Benimaru-Kabu)	Inoculated	2	++++	Very heavy	15
	Control	2	++	—	—
<i>B. cernua</i> .	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. oleracea</i> (Nambu-Kanran)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Horyo)	Inoculated	2	—	—	—
	Control	2	—	—	—
Do (Miyashige)	Inoculated	2	—	—	—
	Control	2	—	—	—
Do (Nerima)	Inoculated	2	—	—	—
	Control	2	—	—	—

Days kept in moist chamber : 3.

TABLE 43. Results of inoculation experiment with conidia from *Brassica Rapa* (Shiromaru-kabu)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica Rapa</i> (Shiromaru-Kabu)	Inoculated	3	++++	Heavy	7
	Control	3	+	—	—
Do. (Tokinashi-Kokabu)	Inoculated	3	++++	Heavy	15
	Control	3	+	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Nerima)	Inoculated	3	—	—	—
	Control	3	—	—	—
<i>Eutrema Wasabi</i>	Inoculated	2	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber : 5.



VIII. Inoculation experiments with conidia from *Brassica Rapa*

## Experiment 1

(Nov. 1, 1931; M. ONOGUCHI)

Inoculations were made on plants of *Brassica Rapa*, *Raphanus sativus* var. *macropodus*, *Eutrema Wasabi* and *Capsella Bursa-pastoris* var. *auriculata*. Infection was secured only on the original host, *Brassica Rapa* (Table 43).

## Experiment 2

(Oct. 24, 1932, T. KATSUKI, R. MIYAZAKI and I. YAMAGUCHI)

Plants of *Brassica Rapa*, *B. japonica* var. *indivisa*, *B. japonica*, *B. chinensis*, *B. cernua*, *Raphanus sativus* var. *macropodus*, *Arabis hirsuta* and *Capsella Bursa-pastoris* var. *auriculata* were selected for inoculation. The inoculation gave positive results only on the plants of *Brassica japonica* var. *indivisa* and *B. Rapa* (Table 44).

TABLE 44 Results of inoculation experiment with conidia from *Brassica Rapa* (Tennōji-kabu)

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Brassica Rapa</i> (Tennōji-kabu)	Inoculated	2	+++	Moderate	5
	Control	1	—	—	—
<i>B. japonica</i> var. <i>indivisa</i> .	Inoculated	1	++	Moderate	9
	Control	1	—	—	—
<i>B. japonica</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. chinensis</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. cernua</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Raphanus sativus</i> var. <i>macropodus</i> (Miyashige)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Arabis hirsuta</i>	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>Capsella Bursa-pastoris</i> var. <i>auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber: 2.

TABLE 45. Results of inoculation experiment with conidia from *Raphanus sativus* var. *macropodus* f. *Horyo*

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Raphanus sativus macropodus</i> (Nerima)	Inoculated	2	++++	Heavy	7-14
	Control	2	+	—	—
Do. (Shōgoin)	Inoculated	2	++++	Heavy	14
	Control	2	+	—	—
<i>Brassica juncea</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Capsella Bursa-pastoris auriculata</i>	Inoculated	2	—	—	—
	Control	2	—	—	—

Days kept in moist chamber: 3.

## IX. Inoculation experiments with conidia from

*Brassica sativus* var. *macropodus*

## Experiment 1

(Oct. 31, 1931; T. EGAMI)

With conidia from f. *Horyo*

Besides the original host, plants of *Brassica juncea* and *Capsella Bursa-pastoris* var. *auriculata* were inoculated. Heavy infection occurred on the original host, while the other plants remained uninfected (Table 45).

## Experiment 2

(Nov. 6, 1931; T. EGAMI)

With conidia from f. *Miyashige*

Just as in the previous experiment only the original host, *Raphanus sativus* var. *macropodus*, was infected. *Eutrema Wasabi*, which was newly added this time, also gave no infection (Table 46).



TABLE 46. Results of inoculation experiment with conidia from *Raphanus sativus* var. *macropodus* f. *Miyashige*

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Raphanus sativus macropodus</i> (Nerima)	Inoculated	2	++++	Heavy	12
	Control	2	—	—	—
Do. (Shogoin)	Inoculated	2	++++	Heavy	12
	Control	2	—	—	—
<i>Brassica chinensis oleifera</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>B. cernua</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Eutrema Wasabi</i>	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>Capsella Bursa-pastoris auriculata</i>	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber: 3.

TABLE 47. Results of inoculation experiment with conidia from *Raphanus sativus* var. *macropodus* f. *Nerima*

Plants		Number of pots	Results		Incubation period (days)
			Pustules	Degree of infection	
<i>Raphanus sativus macropodus</i> (Nerima)	Inoculated	2	++++	Most heavy	7
	Control	2	—	—	—
Do. (Shogoin)	Inoculated	2	++	Moderate	9
	Control	2	—	—	—
Do. (Miyashige)	Inoculated	2	++++	Very heavy	9
	Control	2	—	—	—
<i>Brassica Rapa</i> (Tennoji-Kabu)	Inoculated	2	—	—	—
	Control	1	—	—	—
<i>B. chinensis</i> (Seppaku-Taisai)	Inoculated	1	—	—	—
	Control	1	—	—	—
<i>B. pekinensis</i> (Chiifu-Hakusai)	Inoculated	2	—	—	—
	Control	2	—	—	—
<i>B. oleracea</i> (Nambu-Kanran)	Inoculated	1	—	—	—
	Control	1	—	—	—

Days kept in moist chamber: 3.

## Experiment 3

(Oct. 13, 1932; T. KATSUKI, R. MIYAZAKI and I. YAMAGUCHI)

With conidia from f. *Nerima*

Plants of *Brassica Rapa*, *B. chinensis*, *B. pekinensis* and *B. oleracea* were newly used this time. None of them were infected. *Raphanus sativus* var. *macropodus* was the only species on which infection resulted (Table 47).

## DISCUSSION

When the results of the preceding inoculation experiments are minutely appreciated, the following facts will be naturally understood.

In the first place, the fungus on shepherd's purse infects only its original host, but not other crucifers such as *Draba nemorosa* var. *hebecarpa*, *Eutrema Wasabi*, *Brassica japonica* and its variety *indivisa*. At the same time, fungi on various crucifers other than shepherd's purse are unable to infect the shepherd's purse. Similar results were obtained by HIURA (1930) when he inoculated shepherd's purse with conidia from rape and radish. The inoculation experiments performed by PAPE and RABBAS (1920) show that the fungus on shepherd's purse failed to infect plants of *Brassica Napus*, *Raphanus sativus*, *R. oleiferus*, *Cheiranthus Cheiri*, *Sinapis arvensis* and *Sisymbrium sinapistrum*. From these items of evidence the fungus on *Capsella Bursa-pastris* var. *auriculata* may be safely distinguished as a distinct biologic form.

Secondly, with the fungus on *Arabis hirsuta* no infections are secured on the plants of *Draba nemorosa* var. *hebecarpa*, *Eutrema Wasabi* and *Brassica japonica* var. *indivisa*. Here is one thing to be noted, that is to say, in the experiment made with this strain of fungus a slight occurrence of the disease was observed in both inoculated and control pots of the shepherd's purse. As already pointed out, however, it seems to be difficult to attribute this only



to the fungus employed. However it may be, the pustules produced were few and the incubation period was very long different from usual. Therefore, it is reasonable to consider that this rather uncertain point only cannot prevent the Arabis strain from being separated as a biologic form.

Thirdly, the fungus on *Draba nemorosa* var. *hebecarpa* does not infect the plants of *Capsella Bursa-pastoris* var. *auriculata*, *Arabis hirsuta*, *Cardamine flexuosa*, *Eutrema Wasabi*, *Raphanus sativus* var. *macropodus* and three species of *Brassica* used. But infection occurs on its original host with certainty. These facts will enable us to treat the present strain as another distinct form of *Albugo candida*.

The fungus on *Eutrema Wasabi*, judging from its specialized pathogenicity, may also be considered as distinct from those above mentioned.

The results of the inoculations made on various plants of the genus *Brassica* with the conidia from four species of the same genus are more or less complicated. Putting this and that together, however, it may be concluded that no specialized form can be distinguished among the fungi on *Brassica cernua*, *B. chinensis*, *B. pekinensis* and *B. Rapa*. In connection with these four species, the results of the inoculations will be reviewed again in the following.

(1) With the fungus on *B. cernua*, the results were positive on *B. Rapa*, *B. japonica* var. *indivisa*, *B. pekinensis* and its original host, while negative on *B. chinensis*, *B. japonica*, *Raphanus*, *Arabis* and *Capsella*.

(2) With the fungus on *B. chinensis*, positive on *B. pekinensis*, *B. japonica* var. *indivisa* and its original host, while negative on *B. cernua*, *B. japonica*, *B. pekinensis*, *B. Rapa*, *B. oleifera*, *Raphanus*, *Arabis* and *Capsella*.

(3) With the fungus on *B. pekinensis*, positive on *B. Rapa*, *B. japonica*, *B. japonica* var. *indivisa* and its original host, while negative on *B. cernua*, *B. chinensis* var. *Kukitachina*, *B. oleracea*, *Raphanus* and *Capsella*.

(4) With the fungus on *B. Rapa*, positive on *B. japonica* var. *indivisa* and its original host, while negative on *B. cernua*, *B. chinensis*, *B. japonica*, *Raphanus*, *Arabis*, *Capsella* and *Eutrema*.

The results of the cross-inoculations in relation to the above four species may be summarized in the following table.

TABLE 48. A summary of the results of inoculation experiments with conidia from four different Brassica plants

Plants Inoculated Sources of conidia	<i>B. cernua</i>	<i>B. chinensis</i>	<i>B. pekinensis</i>	<i>B. Rapa</i>
<i>B. cernua</i>	+	-	+	+
<i>B. chinensis</i>	-	+	+	-
<i>B. pekinensis</i>	-	-	+	+
<i>B. Rapa</i>	-	-	-	+

As will be seen in the above table, the fungus from *B. cernua* did not infect the plants of *B. chinensis*, and *vice versa*. The fungus from *B. cernua* infected the plants of *B. pekinensis*, and with the fungus from *B. pekinensis* infection could not occur on the plants of *B. chinensis*. There seem to exist some questionable points in these results. However, the above fact only cannot constitute a reason for distinguishing the cernua strain from the chinensis strain, since the plants of *B. pekinensis* and *B. japonica* were equally infected with the conidia of both cernua and chinensis strains.

A similar relationship is also found between *B. chinensis* and *B. Rapa*. However, it must be well remembered that the plants of *B. japonica* var. *indivisa* were infected with the conidia from both of these species.

As recently as 1930 HIURA distinguished the fungus on rape (*B. chinensis* L. var. *oleifera* MAK. = *B. campestris* L. subsp. *chinensis* MAK.) and Chinese mustard (*B. juncea* COSS.) from each other as distinct biologic forms. The writers have at present no data in



regard to these two forms. Apart from that, it may be said that the fungi on *B. cernua*, *B. chinensis*, *B. pekinensis* and *B. Rapa* cannot be biologically distinguished from one another.

The fungus from radish (*Raphanus sativus* var. *macropodus*) failed to infect six species and one variety of *Brassica* employed as well as one species of *Capsella*. These results of the writers' experiments coincide generally with those of HIURA (1930) and support his attempt to regard the radish strain as a distinct biologic form.

#### Conclusion

From what has been discussed in the preceding pages the following conclusions may be induced:

The species *Albugo candida* is a collective species including at least two morphologically distinct forms. The one is represented by the fungi on *Brassica* and *Raphanus*, and the other by those on *Cardamine flexuosa*, *Capsella Bursa-pastoris* var. *auriculata*, *Draba nemorosa* var. *hebecarpa* and *Arabis hirsuta*. The conidia from the plants of the former group generally measure  $20 \times 18 \mu$ , while those from the latter generally  $15.5 \times 14.5 \mu$ . It is of special interest that the host plants of the former are all cultivated plants, while those of the latter are wild.

It is considered quite reasonable to treat these two forms as varieties in the taxonomical sense. The writers hereupon wish to establish two new varieties within the species *Albugo candida*, proposing the name *microspora* for the one and *macrospora* for the other.

Biologically, on the other hand, widely extended specialization exists in this species. As far as the writers' investigation goes, the following five strains may be asserted with certainty or high probability to represent the distinct biologic forms of *Albugo candida*: To be noted according to the host plant, (1) *Capsella Bursa-pastoris* var. *auriculata*, (2) *Draba nemorosa* var. *hebecarpa*, (3) *Arabis hirsuta*, (4) *Raphanus sativus* var. *macropodus*, (5) *Brassica cernua*, *B. chinensis*, *B. pekinensis* and *B. Rapa*.

In other words, the var. *microspora* include three biologic forms and the var. *macrospora* two forms, so far as the writers have investigated.

#### Summary

1. In order to ascertain the existence of morphological as well as biological specialization within the species *Albugo candida*, the present investigation was carried out.

2. To make a biometrical study of conidia produced on various cruciferous plants was the main work of this investigation and then with these conidia to make cross-inoculation experiments.

3. As the conidium dimensions of fungi are known to be considerably influenced by environmental factors, special care was taken in this respect. Thus as many persons as possible took part in measuring the conidia which were obtained from various sources growing under different conditions. Variations in the dimensions of a definite number of conidia were shown in tables and also plotted into curves.

4. The conidia from the *Brassica* and *Raphanus* plants generally measure  $20 \times 18 \mu$ , while those from the *Cardamine*, *Capsella*, *Draba* and *Arabis* plants generally  $15.5 \times 14.5 \mu$ . Thus a difference of approximately 4-5 microns is proved to exist between these two groups of strains. The products of conidium length multiplied by width were calculated and arithmetically averaged. In this way the value of the former group becomes 364.0081, while that of the latter, 218.3900, the ratio being 1.67.

5. Two fairly distinct forms were thus found through the biometrical studies of the conidia and they were considered due to be treated as varieties. The name "var. *macrospora*" is proposed for the fungi on *Brassica* and *Raphanus*, and "var. *microspora*" for those on *Cardamine flexuosa*, *Capsella Bursa-pastoris* var. *auriculata*, *Draba nemorosa* var. *hebecarpa* and *Arabis hirsuta*.

6. The conidia produced on the plants cultured in the glasshouse were somewhat reduced in dimension.



7. Inoculation experiments were carried out with conidia from *Capsella Bursa-pastoris* var. *auriculata*, *Draba nemorosa* var. *hebecarpa*, *Arabis hirsuta*, *Eutrema Wasabi*, *Raphanus sativus* var. *macropodus*, *Brassica cernua*, *B. chinensis*, *B. pekinensis* and *B. Rapa*.

8. The results obtained revealed the existence of biologic specialization and five distinct forms were proved; namely, the forms on (1) *Capsella Bursa-pastoris* var. *auriculata*, (2) *Draba nemorosa* var. *hebecarpa*, (3) *Arabis hirsuta*, (4) *Raphanus sativus* var. *macropodus* and (5) *Brassica cernua*, *B. chinensis*, *B. pekinensis* and *B. Rapa*.

9. Careful field observation agreed pretty well with results of the inoculation experiments.

10. The Albugo on *Eutrema Wasabi* may be distinct biometrically and biologically from the fungi on the other cruciferous plants employed.

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