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Change in Size Measurements of Powdery Mildew Conidia in Relation to Air Temperature

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氣溫에 따른 흰가루病菌 分生胞子 크기 測定値의 變化

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ABSTRACT: Nine species of powdery mildew fungi were examined to understand the change in size of conidia in relation to air temperature. Of these, *Sphaerotheca aphanis*, *S. fusca*, and *S. pannosa* showed constant value of conidial sizes regardless of changes in air temperature. The length/width ratio in the conidia of *Erysiphe artemisiae* and *E. sordida* increased as the air temperature rose. *E. cichoracearum* gave the result against that shown in the above two species of *Erysiphe*. The conidia of *Microsphaera pseudolonicerae* became decreased in their width as the air temperature fell. The length/width ratio of conidia was markedly increased. *M. alphitoides* and *M. robiniae* showed variable size measurements in conidia regardless of changes in air temperature and studies for it needed for additional examination in future.

KEYWORDS: powdery mildews, anamorph, conidial size

Powdery mildew fungi are classified as based on the location and type of the mycelium and the characteristics of the asci, ascospores, and cleistothecial appendages produced by their teleomorphic states (Blumer, 1967; Braun, 1987). Taxonomy of the anamorphic states has been largely proceeded, independently, the teleomorphic states. A rich variety of morphological characteristics is reported for the conidial states of powdery mildew fungi (Boesewinkel, 1980; Shin, 1988). Important characteristics produced in the anamorphic states of powdery mildews are the production of conidia singly or in chains, the presence or absence of conspicuous fibrosin bodies, the appressoria, the size and shape of the conidia, and the position and type of their germ tubes (Boesewinkel, 1980; Shin, 1988).

When conidia are used in taxonomy, it is the size of conidia which is most commonly used to characterize species (Yarwood, 1978). Size of conidia is reported to be fairly constant for a given host in a given environment (Blumer, 1933, 1967) but to be various with host nutrition (Neger, 1902), age and vigour of host leaves (Neger, 1902; Fischer, 1957), nutrition of host leaves (Zwirn, 1943), season (Sawada, 1927; Homma, 1937), humidity (Bouwens, 1924), host species (Bouwens, 1924; Homma, 1937) and undetermined factors (Yarwood, 1957). Therefore, the size measurements of conidia as well as shape are currently used in the taxonomy of Erysiphaceae (Blumer, 1967; Braun, 1987; Shin, 1988, 1989).

Among the environmental factors that have been known to affect a change in size of powdery mildew conidia, air temperature was studied by Sawada (1927) and Homma (1937). In his taxonimic work on the Korean powdery mildew fungi, the author also recognized that size measurements of conidia often deviate from those of earlier workers and were not consistant with his fresh materials collected at different seasons.

Therefore, this work was made to know the ef-

fect of air temperature on the size measurements of powdery mildew conidia. Since air temperature is not regarded as the only factor that affects the size value of conidia, studies on the other factors should be followed.

Materials and Methods

Powdery Mildew Fungi Examined: Based on the morphological characteristics of the anamorphs, powdery mildew fungi are known to be classified into three groups, viz., the first producing conidia in chains on conidiophores with crenate edge, the second producing conidia in chains on conidiophores with sinuate edge, and the third producing conidia singly on conidiophores (Shin, 1988). Therefore, each three species of powdery mildew fungi from three groups were examined (Table 1). Each host plant species is widely distributed at Kangnung district (Chibyon-dong, Ponam-dong, Yuchon-dong) and usually infected with powdery mildew fungi until they are withered in autumn.

Collection and Preservation of Conidia: Each of the leaves infected with powdery mildew fungus was collected at random date from May to November 1991. Identification of the powdery mildew species was made with the fresh materials at the day of collection or at the next day by keeping them in polyethylene bags at room temperature. In the previous work (Shin, 1988), each of nine host plants was known to be infected with each one species of powdery mildew fungus. Therefore, after confirming that the collections were infected with the powdery mildew species to be studied, each material was dried and preserved in the herbarium SMK (the author's private mycological herbarium) until examined.

Restoring of Dried Conidia: To restore the shriveled structure of the conidia on dried leaves, a small piece of infected leaf tissue was soaked in a few drops of lactic acid on a slide glass and warmed up by holding it carefully about 5 seconds above a small flame. After cooled enough to handle, the fungus was detached from the leaf tissue and mounted in lactic acid for light microscopy.

Measurement of Conidia: Under 400 x magnification, length and width of the conidia were measured and the length/width (L/W) ratio was calculated from these measurements at each collection. Each value was obtained by measuring 40 conidia selected at random.

Temperature Data: Air temperature informations at Kangnung district were obtained from the Kangnung Meteorological Observatory. Since this

Table 1. List of powdery mildew fungi examined and their host plants.

Powdery mildew species[z]	Host plant species[y]	Mode of conidia production and edge line
Sphaerotheca aphanis	*Potentilla freyniana* Bornm.	in chains, crenate
S. fusca	*Lactuca indica* var. *laciniata* (O. Kuntze) Hara	in chains, crenate
S. pannosa	*Rosa multiflora* Thunb.	in chains, crenate
Erysiphe artemisiae	*Artemisia princeps* var. *orientalis* (Pampan.) Hara	in chains, sinuate
E. cichoracearum	*Ambrosia artemisiifolia* var. *elatior* Desc.	in chains, sinuate
E. sordida	*Plantago asiatica* L.	in chains, sinuate
Microsphaera alphitoides	*Quercus aliena* Bl.	singly
M. pseudolonicerae	*Cocculus trilobus* DC.	singly
M. robiniae	*Robinia pseudo-acacia* L.	singly

[z]Identification was made as based on *Erysiphaceae of Korea* (Shin, 1988).
[y]Identification was made as based on *Illustrated Flora of Korea* (Lee, 1979).

Table 2. Size measurements of conidia and their mean value of length/width ratio in *Sphaerotheca aphanis* on *Potentilla freyniana.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
May 16	24.8-32.0 x 11.7-17.6	1.94
Jun 1	22.5-27.9 x 11.7-18.0	1.75
Jun 11	23.4-29.3 x 12.2-15.8	1.87
Jun 24	22.5-30.6 x 12.2-17.1	1.85
Jul 10	22.5-31.1 x 11.7-18.9	1.68
Jul 21	21.6-29.3 x 12.6-16.2	1.79
Sep 12	23.4-30.2 x 11.7-16.7	1.96
Oct 2	23.9-32.0 x 13.1-16.2	1.90
Nov 16	24.3-30.2 x 12.2-15.8	1.92

[z]Each measurement was obtained from 40 conidia selected at random.
[y]Each value of length/width ratio is the mean of 40 conidia selected at random.

Table 3. Size measurements of conidia and their mean value of length/width ratio in *Sphaerotheca fusca* on *Lactuca indica* var. *laciniata.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
Jun 24	25.2-33.3 x 12.2-19.4	1.80
Jul 18	24.8-32.9 x 13.5-18.9	1.80
Jul 28	24.8-32.0 x 13.2-19.8	1.76
Aug 12	25.2-33.3 x 13.1-18.0	1.83
Aug 24	24.8-32.9 x 11.7-17.6	1.95
Sep 6	26.1-32.9 x 12.6-18.5	1.83
Sep 18	24.3-32.9 x 13.5-16.7	1.86
Sep 28	24.8-31.0 x 13.1-18.5	1.82
Oct 12	27.9-36.5 x 14.0-19.4	1.93
Oct 30	27.5-34.2 x 14.0-20.3	1.80

[z] and [y] See Table 2.

work was made to know the general correlative phenomenon between air temperature and size values of conidia, air temperature informations were calculated to show the mean temperature at each 10 days intervals.

Results and Discussion

In powdery mildew fungi, any general principle on the change of size values of conidia in relation to the environmental factors has not found. Host nutrition, age and vigour of host leaves, nutrition of host leaf, season, humidity, host species, and undetermined factors have been considered as the factors that more or less affect the size value of conidia (Yarwood, 1978). This work dealed with the effect of air temperature.

Of the nine species of powdery mildew fungi examined in this work, *Microsphaera pseudolonicerae* on *Cocculus trilobus* showed the most distinct change in size measurements and L/W ratio of conidia in relation to air temperature (Table 9; Fig. 2). As the air temperature fell, the width of conidia became markedly smaller but the length was generally unaffected. Thus, L/W ratio of coni-

Table 4. Size measurements of conidia and their mean value of length/width ratio in *Sphaerotheca pannosa* on *Rosa multiflora* cultivated.

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
May 16	18.5-26.6 x 9.5-14.4	1.82
May 28	18.9-25.7 x 9.9-14.9	1.90
Jun 4	21.2-27.9 x 10.4-14.4	1.85
Jun 29	18.9-25.7 x 9.5-15.3	1.86
Jul 30	19.4-25.2 x 10.8-14.9	1.82
Aug 25	20.7-26.6 x 10.8-14.9	1.84
Oct 14	18.9-26.6 x 10.4-15.3	1.82
Nov 7	19.8-25.7 x 10.8-14.4	1.87
Nov 23	19.4-25.2 x 10.4-14.0	1.88

[z] and [y] See Table 2.

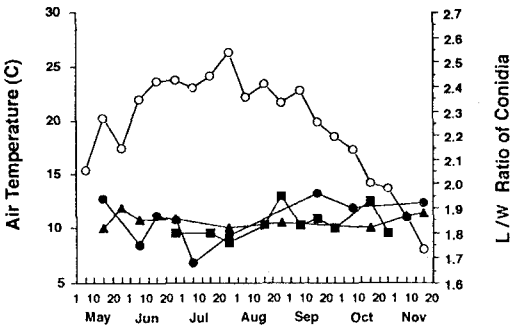

Fig. 1. Fluctuation of mean value of length/width (L/W) ratio in the conidia of *Sphaerotheca aphanis* (●-●), *S. fusca* (■-■), and *S. pannosa* (▲-▲) in relation to air temperature (○-○).

Table 5. Size measurements of conidia and their mean value of length/width ratio in *Erysiphe artemisiae* on *Artemisia princeps* var. *orientalis.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
May 28	22.5-29.3 x 12.2-17.6	1.83
Jun 9	24.8-34.2 x 13.2-16.7	1.99
Jun 24	23.0-34.2 x 11.3-17.6	2.05
Jul 16	25.2-32.0 x 12.6-16.2	2.08
Jul 23	23.0-33.8 x 12.2-16.2	1.98
Sep 8	23.0-33.8 x 13.1-17.1	1.90
Sep 15	25.2-32.0 x 11.7-18.0	2.11
Oct 12	27.9-37.4 x 13.5-22.1	1.81
Oct 30	24.8-35.1 x 14.4-18.0	1.90
Nov 6	23.4-36.5 x 12.6-18.5	1.81

[z] and [y] See Table 2.

dia was markedly increased.

In the three species of *Sphaerotheca, S. aphanis* on *Potentilla freyniana, S. fusca* on *Lactuca indica* var. *laciniata* and *S. pannosa* on *Rosa multiflora* cultivated, L/W ratio of conidia was generally constant and not related to changes in air temperature (Table 2,3,4; Fig. 1). The size value of measurements in conidia was also not changed in relation to air temperature.

In the two species of *Erysiphe, E artemisiae* on *Artemiaia princeps* var. *orientalis* and *E. sordida* on *Planta asiatica,* L/W ratio of conidia was generally decreased as the air temperature fell (Table 5, 7; Fig. 2). In the fungus *E. cichoracearum* on *Ambrosia artemisiifolia* var. *elatior,* however, L/W ratio of conidia became larger as the air temperature went down (Table 6; Fig. 2). This was resulted by decreasing in width and increasing in length of conidia as the air temperature fell.

Of the above three species, *E. sordida* was previously studied by Sawada (1927) under three different temperature coniditions. He recorded that conidia under 30 C were the largest in length and the smallest in width. On the other hand, conidia treated in 21 C were the smallest in length and the largest in width. Therefore, he concluded that L/W ratio of conidia became increased as the air temperature rose. The L/W ratio of conidia measured was reported to be 1.75 at 21

Table 6. Size measurements of conidia and their mean value of length/width ratio in *Erysiphe cichoracearum* on *Ambrosia artemisiifolia* var. *elatior.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
Jun 7	23.0-31.5 x 13.5-17.6	1.70
Jun 22	21.6-32.0 x 14.0-17.1	1.69
Jul 3	23.4-29.7 x 14.0-18.0	1.66
Aug 2	22.5-31.1 x 14.4-18.0	1.69
Aug 28	22.5-30.2 x 14.4-18.0	1.66
Sep 26	24.3-29.7 x 13.5-16.7	1.76
Oct 22	23.9-31.5 x 13.5-18.0	1.82
Nov 2	25.2-33.8 x 12.6-18.0	1.96

[z] and [y] See Table 2.

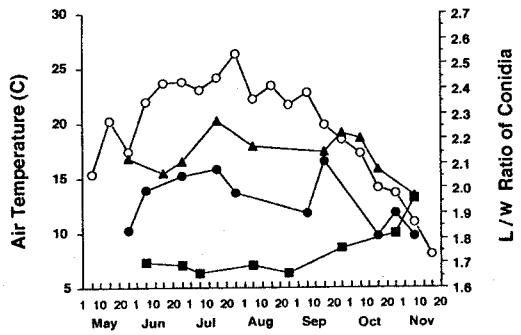

Fig. 2. Fluctuation of mean value of length/width (L/W) ratio in the conidia of *Erysiphe artemisiae* (●-●), *E. cichoracearum* (■-■), and *E. sordida* (▲-▲) in relation to air temperature (○-○).

C, 1.90 at 25 C, and 2.25 at 30 C. Though the change of L/W ratio in relation to air temperature in Sawada's work is in general accordance with the present study, the causes are different each other. In the present study, increase in L/W ratio of conidia was resulted by decreasing the width of conidia. On the other hand, Sawada recorded that increase in L/W ratio of conidia was mainly affected by increasing the length of conidia.

Also in three species of *Microsphaera,* L/W ratio of conidia became larger in general as the air temperature fell. In *M. pseudolonicerae,* length of conidia was generally constant regardless of air temperature, but width of conidia became markedly smaller. Thus, L/W ratio of conidia in this species was increased with decrease of air tmeperature

Table 7. Size measurements of conidia and their mean value of length/width ratio in *Erysiphe sordida* on *Plantago asiatica.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
May 29	30.6-37.8 x 13.5-19.4	2.12
Jun 13	29.3-36.5 x 13.5-17.6	2.06
Jun 24	29.3-36.9 x 13.5-18.9	2.11
Jul 15	24.8-36.0 x 11.7-17.1	2.27
Aug 10	27.0-36.5 x 12.6-17.1	2.17
Sep 14	24.8-34.2 x 12.2-15.8	2.15
Sep 22	27.5-36.5 x 12.6-16.2	2.22
Oct 2	27.9-41.0 x 12.6-18.9	2.20
Oct 18	27.9-34.7 x 13.5-17.6	2.08
Nov 5	25.2-34.2 x 14.0-18.0	1.97

[z] and [y] See Table 2.

Table 8. Size measurements of conidia and their mean value of length/width ratio in *Microsphaera alphitoides* on *Quercus aliena.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
May 16	31.1-39.2 x 15.8-19.8	1.91
Jun 24	29.3-38.7 x 16.7-19.7	1.73
Jul 2	29.3-37.8 x 15.8-18.9	1.85
Aug 1	23.0-32.0 x 14.4-18.5	1.82
Aug 31	27.9-34.2 x 16.2-20.3	1.76
Sep 24	20.7-30.2 x 11.3-15.8	1.83
Oct 14	21.6-32.9 x 13.1-17.6	1.90
Nov 16	23.0-36.0 x 13.5-17.1	1.97

[z] and [y] See Table 2.

(Table 9; Fig. 3). In *M. alphitoides* and *M. robiniae,* however, there were fuluctuations both in L/W ratio and in length and width of conidia (Table 8, 10; Fig. 3).

In *M. alphitoides,* length and width of conidia collected from May to August was much smaller than those from September to November (Table 8). Since the new lesions of powdery mildew were not usually formed from September to November and so most of materials examined were obtained from the old leaves. Therefore, this fluctuation of size value seems to be influenced by the leaf age rather than air temperature. Greater fluctua-

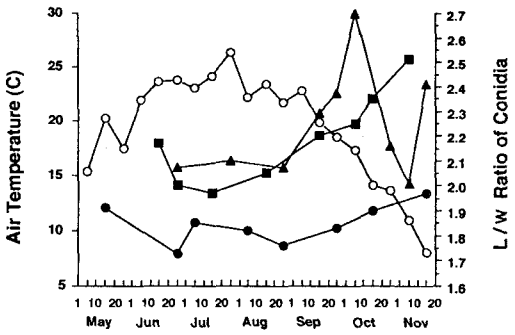

Fig. 3. Fluctuation of mean value of length/width (L/W) ratio inthe conidia of *Microsphaera alphitoides* (●-●), *M. pseudolonicerae* (■-■), and *M. robiniae* (▲-▲) in relation to air temperature (○-○).

Table 9. Size measurements of conidia and their mean value of length/width ratio in *Microsphaera pseudo-lonicerae* on *Cocculus trilobus.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
Jun 17	24.8-38.7 x 12.2-17.6	2.17
Jun 25	26.1-41.0 x 13.5-18.9	2.00
Jul 18	26.6-36.5 x 14.4-18.5	1.97
Aug 16	27.5-39.2 x 14.0-18.9	2.05
Sep 16	27.5-36.0 x 12.6-16.2	2.20
Oct 9	27.0-36.0 x 11.3-18.5	2.25
Oct 17	27.5-33.8 x 11.7-15.5	2.35
Nov 5	27.9-36.0 x 9.9-13.5	2.51

[z] and [y] See Table 2.

Table 10. Size measurements of conidia and their mean value of length/width ratio in *Microsphaera robiniae* on *Robinia pseudo-acacia.*

date collected	measurement of conidia[z] (length x width in μm)	L/W ratio of conidia[y]
Jun 25	22.1-31.1 x 10.4-14.0	2.07
Jul 27	22.5-31.5 x 11.3-14.9	2.10
Aug 23	29.7-36.0 x 13.5-18.0	2.07
Sep 14	22.5-31.0 x 11.3-13.5	2.29
Sep 28	23.9-32.4 x 9.0-13.5	2.37
Oct 9	27.0-39.6 x 10.4-14.0	2.70
Oct 25	22.5-33.3 x 11.3-15.3	2.16
Nov 1	22.5-33.3 x 11.7-16.7	2.01
Nov 14	22.5-34.2 x 9.5-13.5	2.41

[z] and [y] See Table 2.

tion of size values in conidia was observed in *M. robiniae*. Two collections at Aug. 23 and Oct. 19 had larger conidia in length and width than those of the other 7 collections at different dates. This phenomenon seems to be not related to air temperature, but to undetermined factors. One of the possible factors associated is the infection of leaves by the several folial diseases.

摘 要

분생포자 형성 양식에 따라 3 대별된 흰가루병균을 각각 3 종씩 총 9 종을 대상으로 1991년 5월부터 11월까지 채집하였다. 그 중 양지꽃 흰가루병균(*Sphaerotheca aphanis*), 왕고들빼기 흰가루병균(*S. fusca*), 장미 흰가루병균(*S. pannosa*)은 기온의 변화에 무관하게 년중 분생포자 크기가 비슷하였으며, 장폭비도 뚜렷한 변화 양상을 나타내지 않았다. 쑥 흰가루병균(*Erysiphe artemisiae*)과 질경이 흰가루병균(*E. sordida*)은 기온이 상승함에 따라 분생포자의 장폭비가 증가하였으며, 돼지풀 흰가루병균(*E. cichoracearum*)은 기온이 하강할수록 분생포자의 장폭비가 증가하였다. 댕댕이덩굴 흰가루병균(*Microsphaera pseudolonicerae*)은 기온의 하강에 따라 분생포자의 폭이 감소하였으며, 이에 따라 장폭비가 크게 증가하였다. 이러한 경향의 변화는 본 연구에서 처음으로 확인되었다. 그리고 갈참나무 흰가루병균(*M. alphitoides*)과 아까시나무 흰가루병균(*M. robiniae*)은 기온의 변화와 무관하게 분생포자 측정치의 변화가 심했다. 특히 댕댕이덩굴 흰가루병균은 기온의 영향으로 가장 뚜렷한 변화를 나타냈으므로 앞으로 이 연구의 좋은 소재로 판단된다.

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