

## CHAPTER 4

### RESULTS

#### Microclimate

##### *Microclimate of Various Ecosystems*

Microclimate including light intensity, temperature and relative humidity was measured at lichen habitat on one host tree in each forest types. These data represented growing condition of lichens in various ecosystems. Microclimate from TRF, DEF, SF and LMF were recording on *Terminalia citrine*, *Terminalia* sp. *Schima wallichii* and *Schima wallichii* respectively. The data were recorded every 5 minutes for 60 days intervals from every ecosystem during January 2004 to January 2007. Diurnal cycle of microclimatic data derived from averaging one hour measurements of the whole day. Microclimate of the five forest types were described below:

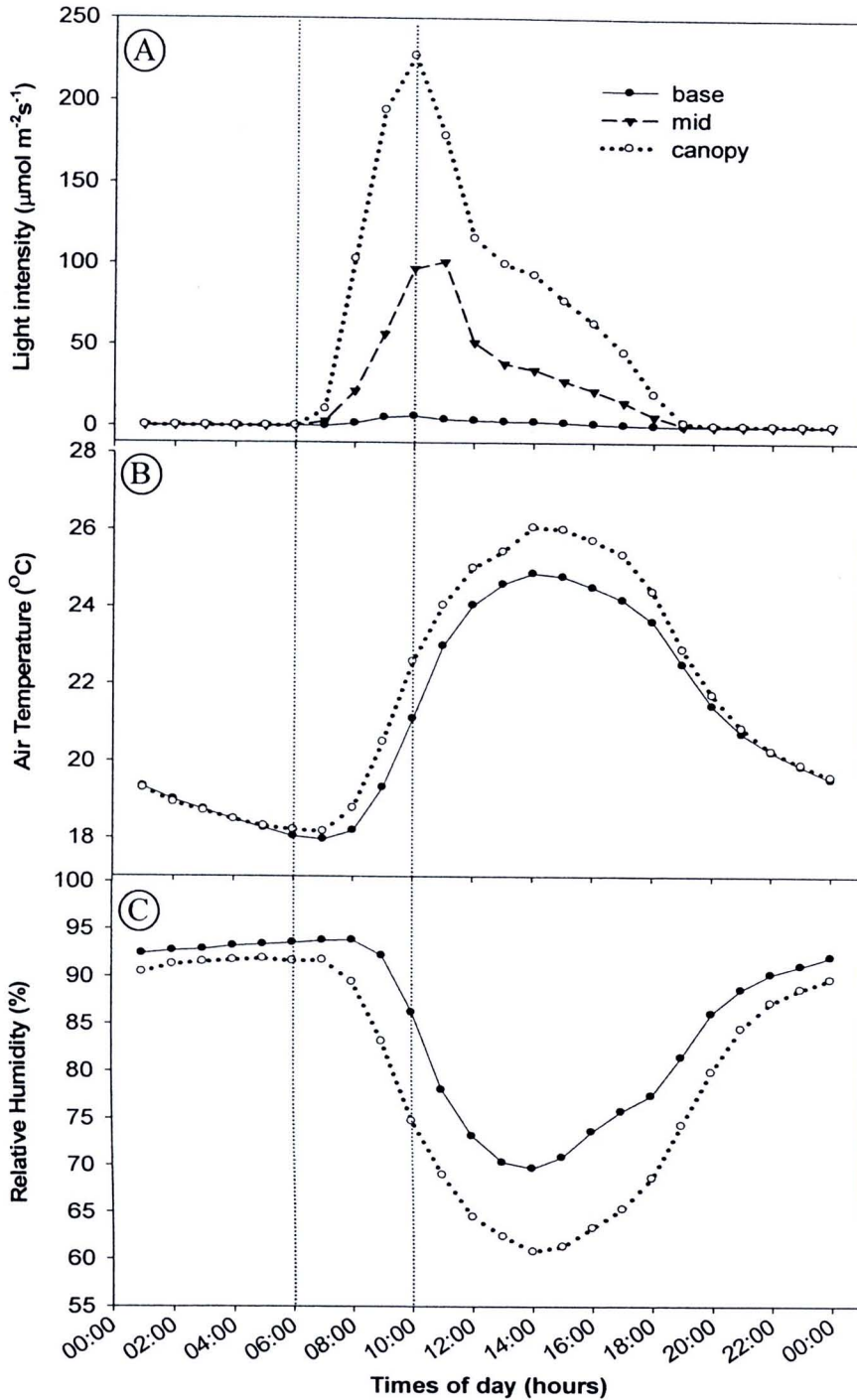
##### ***Tropical Rain Forest***

***Light intensity.*** Light intensity at various tree levels in tropical rain forest varied considerably. High illumination of  $101 \mu\text{mol m}^{-2} \text{s}^{-1}$  was seen at canopy, subsequently lower at mid-trunk and base trees averaged 39, 3  $\mu\text{mol m}^{-2} \text{s}^{-1}$  respectively (see Figure 20A). The highest peaks of illumination at these

levels were 1079, 1247 and 220  $\mu\text{mol m}^{-2} \text{s}^{-1}$  (see Table 3). Average of hourly maximum was 227  $\mu\text{mol m}^{-2} \text{s}^{-1}$  observed at the canopy, subsequently declined at mid-trunk and tree base accounting for 100 and 6  $\mu\text{mol m}^{-2} \text{s}^{-1}$  respectively (see Figure 20A). Microclimate between trees base and mid-trunks in this forest had lower illumination during photosynthetic active period than those observed from SF.

**Temperature.** Mean temperatures during 24 hours were 21.6 and 21.1  $^{\circ}\text{C}$  at canopy and tree base, which was only slightly different. The highest maximum temperature of 33.7  $^{\circ}\text{C}$ , was recorded at canopy in summer (March 2005). This value was the highest ever recorded in this study (see Table 3). Figure 20B showed diurnal cycle of temperature averaged from canopy, which was similar to the tree base. This figure illustrated that the highest averaged temperature was 26.3  $^{\circ}\text{C}$  recorded at 14:00 h, while the lowest 18.5  $^{\circ}\text{C}$  was noted at 7:00 h. Temperatures during photosynthetic active period ranged from 17.9 to 21.1  $^{\circ}\text{C}$  at base and canopy respectively.

**Relative Humidity.** Average values of relative humidity at the base and canopy were 85.2 and 79.8% (see Table 3), of which 3 to 5% differences was obvious as showed in Figure 20C. The lowest values of 39% and 26% were recorded at the tree base and the canopy. However, this figure showed the similarity between canopies of TRF and SF. During photosynthetic active period averaged relative humidity at canopy and base trees were as high as 85 and 91.4%, which was sufficient for photosynthesis of lichens.



**Figure 20** Microclimate from Tropical rain forest averaged from 60 days.

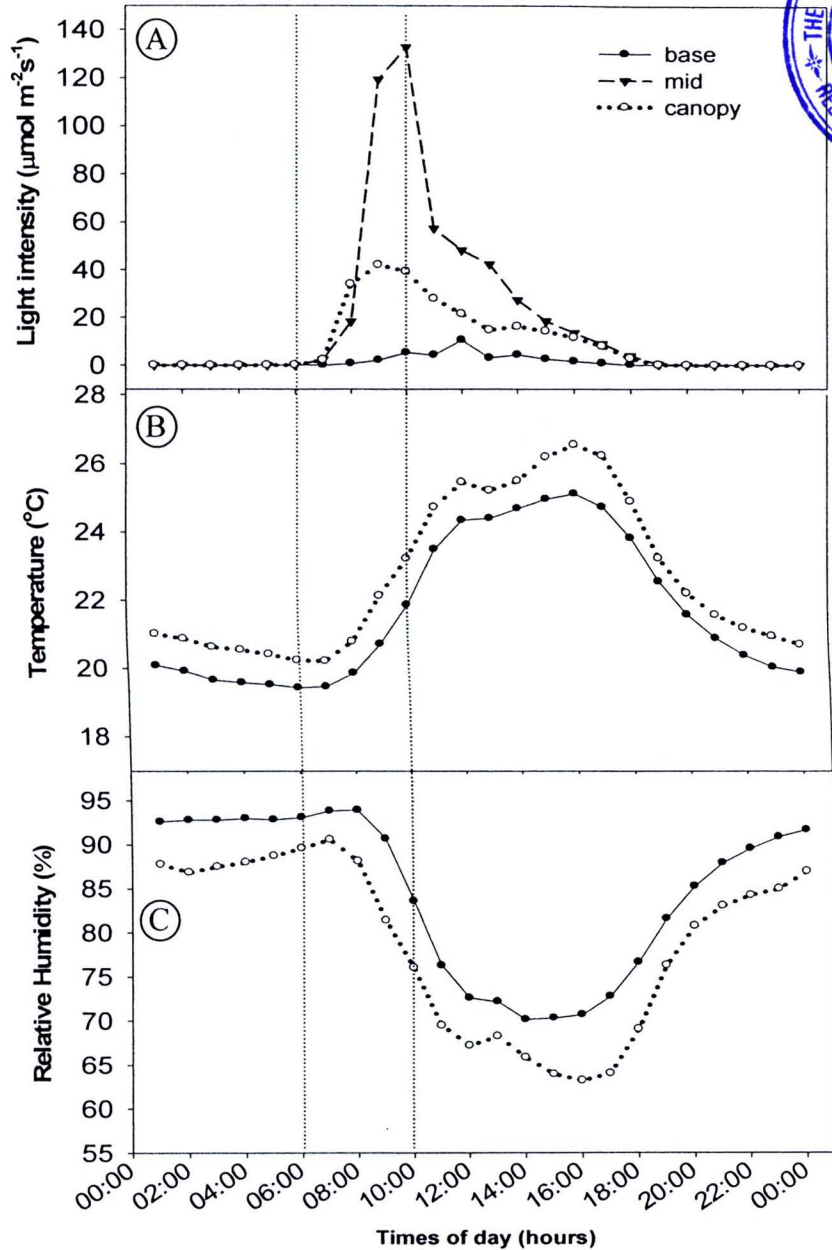
*Note.* From researcher; measurements were recorded during January 2004 to January 2007. Light intensity (A) and Temperature (B) and Relative Humidity (C) Vertical dot lines showed photosynthetic active period (6:00 to 10:00 h).

### ***Dry Evergreen Forest***

***Light intensity.*** Average light intensity during the day times had higher illumination at mid-trunk than canopy and tree base (see Table 3). The highest average value of  $126 \mu\text{mol m}^{-2} \text{s}^{-1}$  was noted at mid-trunk at 10:00 h, while canopy and tree base were 42 (9:00 h) and  $9 \mu\text{mol m}^{-2} \text{s}^{-1}$  (12:00 h) respectively (see Figure 21A). However, light intensity during photosynthetic active period had the highest average value of  $66 \mu\text{mol m}^{-2} \text{s}^{-1}$  at mid-trunk.

***Temperature.*** Mean daily temperature at the canopy and tree base were  $22.6^\circ\text{C}$  and  $21.6^\circ\text{C}$ , which was about  $1^\circ\text{C}$  difference (see Figure 21B). The highest air temperature was  $31.7^\circ\text{C}$  recorded at canopy in March 2004. The largest temperature difference between tree base and canopy were  $25.1^\circ\text{C}$  and  $26.5^\circ\text{C}$  recorded during 16:00 h. Temperature during photosynthetic active period, at canopy and base trees were  $20.4$  and  $21.5^\circ\text{C}$  respectively.

***Relative Humidity.*** Average relative humidity of 74.6 and 80% at tree base and canopy were recorded as showed in Table 3. The largest difference in RH between canopy and tree base was observed in this forest (see Figure 21C), which the difference was approximately 5% throughout the day. The highest hourly averages was observed at 7:00 h at tree base and canopy accounting for 93 and 90.5% respectively. The lowest value of 63.2% was observed at canopy during 16:00 h, while 70.2% during 14:00 h was found at tree base. During photosynthetic active period RH of 79.5 and 85.6% were observed at canopy and tree base.



**Figure 21** Microclimate at dry evergreen forest averaged from 60 days.

*Note.* From researcher; measurements were recorded during January 2004 to January 2007. Light intensity (A) and Temperature (B) and Relative Humidity (C). The dot lines showed photosynthetic active period (6:00 to 10:00 h).

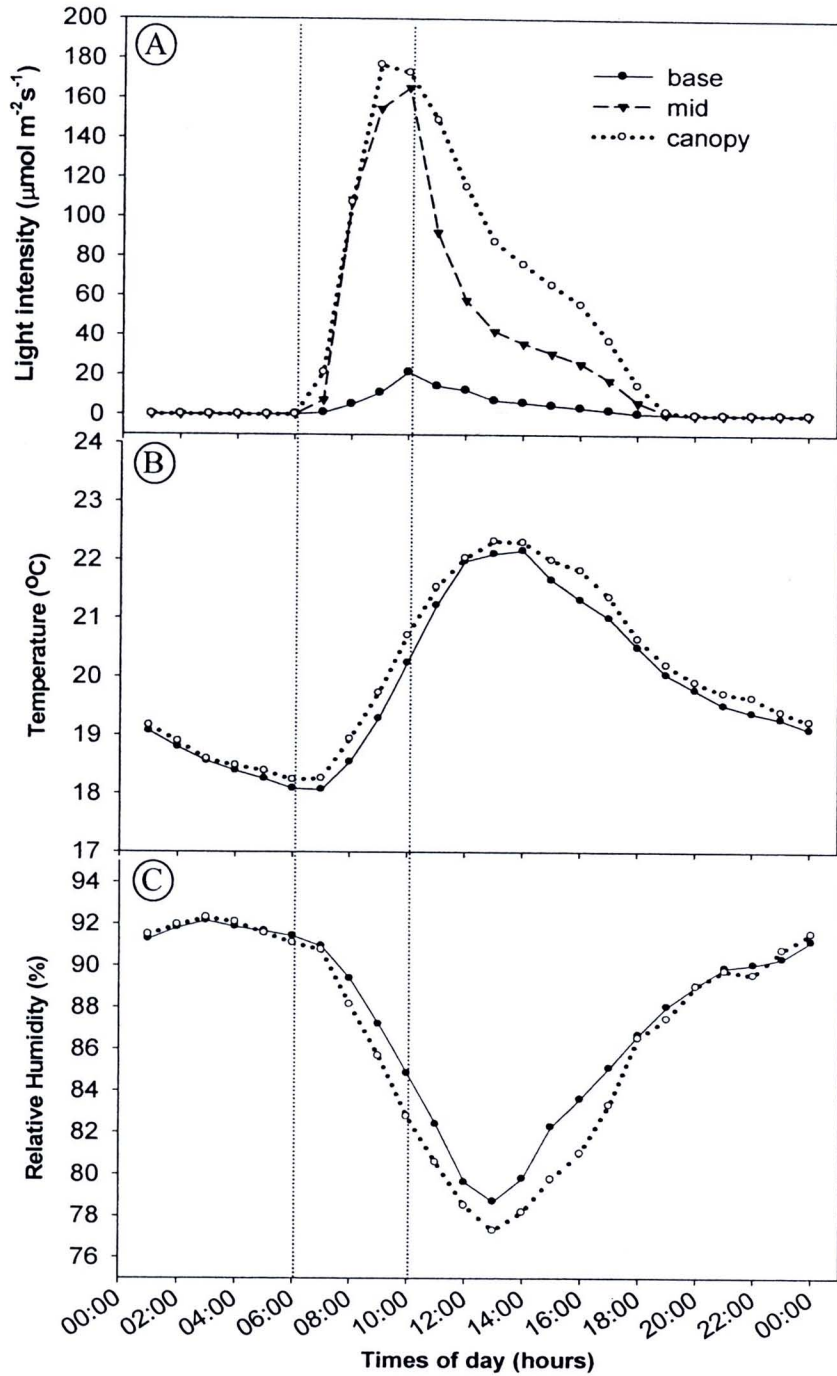
### *Lower Montane Forest*

**Light intensity.** Figure 22A and Table 3 showed that illumination at mid-trunk and canopy nearly were much higher than the tree base. Average light intensities at mid-trunk and canopy were 89 and 62  $\mu\text{mol m}^{-2} \text{s}^{-1}$  and during photosynthetic active period were 165 and 173  $\mu\text{mol m}^{-2} \text{s}^{-1}$  respectively (see Table 3). By contrast light intensity at tree base during the daytime and photosynthetic active period were only 7 and 9  $\mu\text{mol m}^{-2} \text{s}^{-1}$  respectively.

**Temperature.** The lowest temperature at LMF was observed in early morning (6:00 to 7:00 h), whilst the highest occurred during 14:00 h (Figure 22B). Temperature difference between canopy and base trees was less than those observed at TRF and DEF. Mean temperatures at canopy and tree base were 20.0 and 18.1 °C respectively (see Table 3), which was about 2-3 °C cooler area than other areas. The highest mean temperatures at canopy and tree base were 28.5 and 29.1 °C, while the lowest were 12 and 12.2 °C. These were lower than the other areas. In addition, range of temperature during metabolic active period was between 18 to 20.7 °C, which was also lower than other areas.

**Relative Humidity.** Average relative humidities at the canopy and tree base of the LMF were 86.7 and 87.7% respectively (see Table 3). The difference between tree base and canopy was about 1-2% all-days as showed in Figure 22C. This area had higher moisture content in the atmosphere than the other areas. The maximum relative humidity was nearly saturated (99-100%) at canopy and tree base. The minimum relative humidity at canopy and

tree base were 54.1 and 57.2% (see Table 3). In addition, humidity during photosynthetic active period in this area was higher and lasted longer than other forests. Therefore, the photosynthetic period could be longer than other areas.



**Figure 22** Microclimate at Lower montane forest averaged from 60 days.

*Note.* From researcher; measurements were recorded during January 2004 to January 2007. Light intensity (A) and Temperature (B) and Relative Humidity (C). The dot lines showed photosynthetic active period (6:00 to 10:00 h).

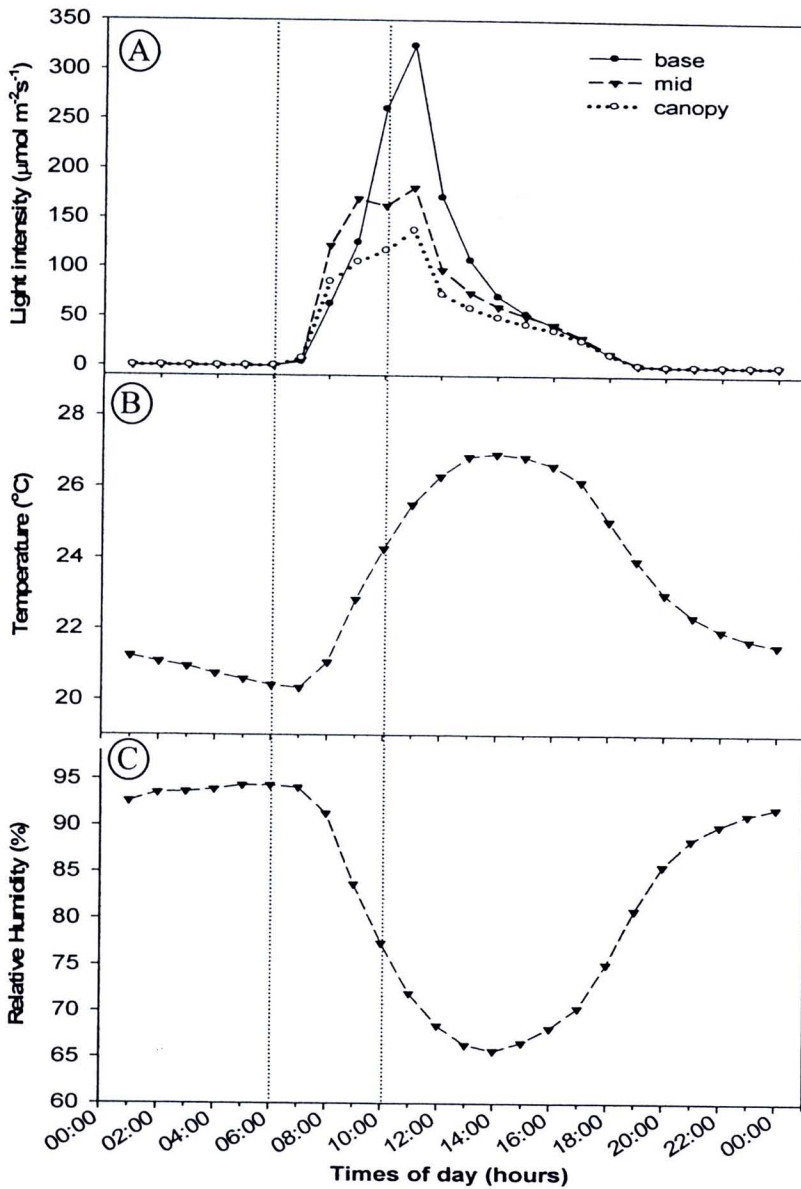
### *Secondary Forest*

**Light intensity.** Average light intensity during the day at the canopy, mid trunk and tree base were 62, 83 and 101  $\mu\text{mol m}^{-2} \text{s}^{-1}$  respectively. Maximum light intensity was recorded at the canopy during 8:10 h in September 2004 accounting for 1426  $\mu\text{mol m}^{-2} \text{s}^{-1}$ , whereas that at the three levels of tree-trunk was higher than 1100  $\mu\text{mol m}^{-2} \text{s}^{-1}$  (see Table 3). However, hourly averages of this factor show that the highest value was recorded at the tree base (see Figure 23A). All three levels of tree-trunk had high illumination comparing with those from other forests. Light intensities during photosynthetic active period, recorded at 6:00 to 10:00 h, were 76-111  $\mu\text{mol m}^{-2} \text{s}^{-1}$ .

**Temperature.** Mean temperature of this area was 23.2°C, which was higher than other areas (see Table 3). The maximum temperature was 31.8 °C recorded in April 2005. The highest mean temperature during daytime was 26.9 °C observed at 14:00 h, which was warmer than other forests (see Figure 23B). Minimum temperature of 14.6 °C was recorded in January 2005, while the hourly minimum averaged 20.3 °C was recorded during 6:00 to 7:00 h (see Figure 23B). Temperatures during photosynthetic active period were 20.3 to 24.3 °C.

**Relative Humidity.** Relative humidity of 95-100% were frequently observed in early morning in hot season and rainy season. Average relative humidity during the daytimes was 83.2%, while the lowest value of 66% was recorded at 14:00 h (see Table 3 and Figure 23C). Relative humidity of 78 to

95 % were recorded during photosynthetic active period. It lasted for almost four hours each day.



**Figure 23** Microclimate of secondary forest averaged from 60 days.

*Note.* From researcher; measurements were recorded during January 2004 to January 2007. Light intensity (A) and Temperature (B) and Relative Humidity (C). The dot lines showed photosynthetic active period (6:00 to 10:00 h).

**Table 3**

*Microclimate at Canopy, Mid-trunk and Tree Base of SF, TRF, DEF and LMF. The Data Presented values of Maximum, Daily Average and Metabolic Active Period of Lichens (\*6:00-10:00 h)*

Ecosystems	Light intensity ( $\mu\text{mol m}^{-2}\text{s}^{-1}$ )			Temperature ( $^{\circ}\text{C}$ )			Relative Humidity (%)			
	Max (peak)	6:00-18:00	Average 6:00-10:00*	Max	Min	Average 24 hr	Max	Min	Average 24 hr	Average 6:00-10:00*
<b>Tropical Rain Forest</b>										
Canopy	1079	101	129	31.8	11.2	21.6	100	26.0	79.8	85.0
Mid-trunk	1247	39	43	-	-	-	-	-	-	-
Base	220	2.7	3.3	33.7	11.1	21.1	98.1	39.1	85.2	91.4
<b>Dry Evergreen Forest</b>										
Canopy	608	20	29	31.7	12.5	22.6	95.4	42.7	74.6	79.5
Mid-trunk	1081	42	66	-	-	-	-	-	-	-
Base	230	3	2.1	29.6	10.6	21.6	98.6	48.3	80	85.6
<b>Lower Montane Forest</b>										
Canopy	989	89	117	28.5	12.0	20.0	99.6	54.1	86.7	86.9
Mid-trunk	939	62	106	-	-	-	-	-	-	-
Base	284	7	9	29.1	12.2	19.7	99.1	57.2	87.7	88.2
<b>Secondary Forest</b>										
Canopy	1163	62	76	-	-	-	-	-	-	-
Mid-trunk	1426	83	111	31.8	14.6	23.2	100	47.1	83.2	87.0
Base	1322	101	107	-	-	-	-	-	-	-

## ***Seasonal Variation of Microclimatic Factors in Various Ecosystems***

Microclimates were measured at time intervals for 60 days during three years of measurement since January 2004 to January 2007 in Tropical rain forest, Dry evergreen forest, Lower montane forest and Secondary forest at KYNP. Variations of microclimate factors in various seasons were observed from this observation.

### ***Light Intensity***

Annual fluctuation of illumination among ecosystems was demonstrated in Figure 24 and Table 4.

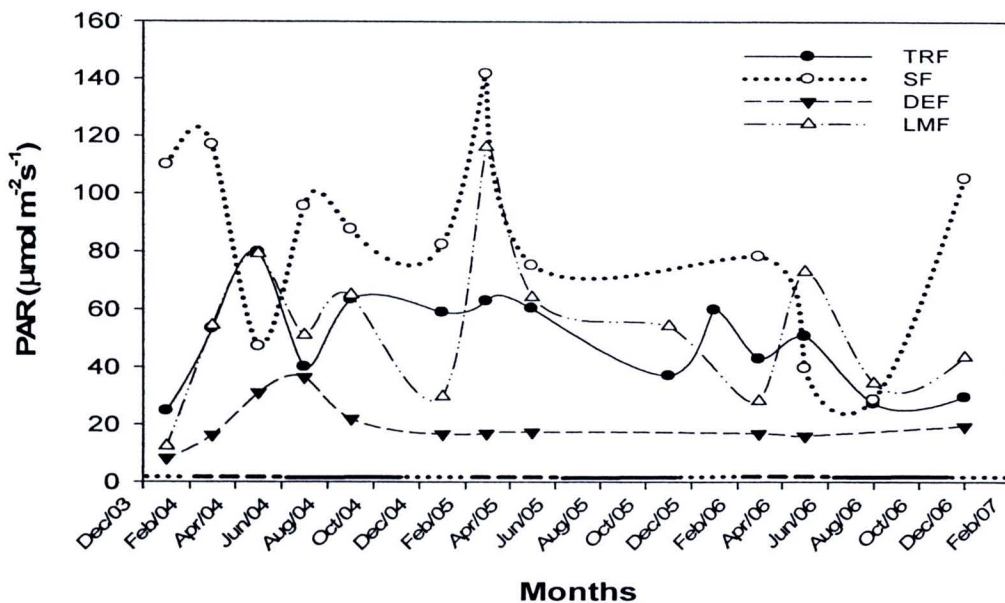
***Secondary Forest.*** This area had higher illumination than other areas throughout the year (see Figure 24). Despite average illumination of SF during rainy season was obviously much lower than the hot and cool seasons, however maximums light intensity was recorded in rainy season at mid trunk level (see Table 4). Peak illumination was observed in February (cool season), because the trees partially shed their leaves in drought season. On the other hand, the hot season showed averages light intensity higher than cool seasons and rainy season.

***Lower Montane Forest.*** This forest had average light intensity in hot season higher than rainy season and cool seasons (see Table 4). Illumination in this area only seconded to SF. Annual average was  $54 \mu\text{mol m}^{-2} \text{s}^{-1}$  lower than SF. The highest illumination occurred in hot seasons, similar to SF (see

Figure 24). High illuminations as much as  $800-900 \mu\text{mol m}^{-2} \text{s}^{-1}$  were recorded in rainy season and hot season at the canopy and mid trunk levels.

**Tropical Rain Forest.** This forest had high illumination only at the canopy in all seasons. The mid trunk level received about half to a quarter, and the tree base had less than 5% of the canopy light. Hot season had the highest average illumination than other seasons at all level along tree trunks, with the maximum intensity observed at the mid trunk (see Table 4).

**Dry Evergreen Forest.** Illumination in this forest through out the year was the lowest among all forests at every level observed (see Figure 24). Average light intensity was approximately  $20 \mu\text{mol m}^{-2} \text{s}^{-1}$  during most period of observation. Maximum and the highest average light intensities were recorded from mid trunk in hot season. (see Table 4).



**Figure 24** Seasonal fluctuation of light intensity at lichen habitats in various ecosystems.

*Note.* From researcher; light intensities were measured during February 2004 to January 2007 at KYNP (..... Cool season, - - - Hot season and — Rainy season).

**Table 4**

*Light Intensity (6:00-18:00 h) Along Vertical Strata of the Trees in Various Seasons and Forest Types at KYNP*

Microclimate		Light intensity ( $\mu\text{mol m}^{-2}\text{s}^{-1}$ )											
		Secondary Forest			Lower Montane Forest			Tropical Rain Forest			Dry Evergreen Forest		
Seasons	Tree levels	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average
Hot season	Canopy	464	-	90	925	-	142	1077	-	102	442	-	21
	Mid-trunk	811	-	120	825	-	101	1248	-	53	1081	-	50
	Base	890	-	117	234	-	14	200	-	3.4	231	-	3.8
Rainy season	Canopy	1014	-	21	990	-	95	703	-	90	608	-	19
	Mid-trunk	1426	-	26	939	-	39	1044	-	37	864	-	49
	Base	1322	-	39	285	-	6.5	221	-	2.6	127	-	1.7
Cool season	Canopy	1163	-	62	387	-	57	671	-	104	226	-	15
	Mid-trunk	1075	-	75	709	-	59	241	-	26	492	-	28
	Base	1174	-	125	69	-	4.2	117	-	2.2	33	-	2.4

## **Temperature**

Annual mean temperature at LMF was obviously lower than the other three forests. Moreover, seasonal variation of the former was greater than the others as showed in Figure 25 and Table 5.

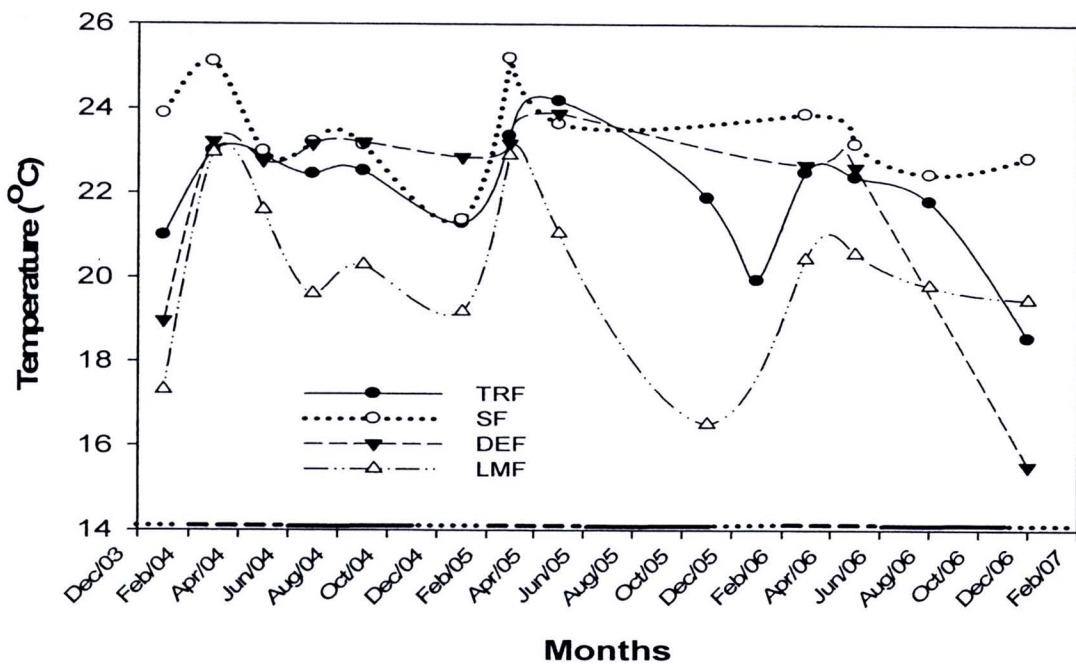
**Secondary Forest.** Annual mean temperature was 23.4°C, which was obviously higher than the other areas (see Figure 25). Maximum temperature of 31.9°C and maximum mean temperature of 24.4°C were observed in hot seasons. Those in rainy season and cool season were lower averaged 23.1 and 22.7°C were noted respectively (see Table 5).

**Dry Evergreen Forest.** Annual mean temperature in hot season was higher than the other two seasons at the canopy and tree base levels, despite data at the mid trunk was not available (see Table 5). However, difference between levels (canopy vs. tree base) was less than seasonal variations. Maximum temperature as high as 31.7 °C was recorded at the canopy in hot season, whereas the lowest temperature of 10.7 °C was noted at the tree base in cool season. This value was the lowest recorded in this study. Moreover, annual mean temperature at tree base in the cool season of this forest was as low as that of the LMF (see Table 5).

**Tropical Rain Forest.** Although locations of TRF and DEF were next to each other. However, mean annual temperature in TRF appeared to fluctuated lesser than DEF (see Figure 25 and Table 5), and was lower than DEF throughout the year. The maximum temperatures as high as 33.7 °C was recorded at canopy in hot season, and this value was the highest temperature recorded in this study. Remarkably, among the maximum temperatures

observed in all season, the lowest value was noted in rainy season. This situation was similar those observed in DEF and SF.

**Lower Montane Forest.** Seasonal variation of temperature in LMF was greater than other forests (see Figure 25). Mean annual temperature in this forest was 20.2 °C, which was obviously lower than other forests. The highest maximums and the lowest minimums temperatures were 29.1 and 12 °C measured at tree base in hot season and at canopy in cool season respectively (see Table 5).



**Figure 25** Seasonal fluctuation of temperature at lichen habitats in various ecosystems.

*Note.* From researcher; Temperatures were measured during February 2004 to January 2007 at KYNP ( ..... Cool season, - - - Hot season and ——— Rainy season).

**Table 5**

*Air Temperature Along Vertical Strata of the Trees in Various Seasons and Forest Types at KYNP*

Microclimate		Air Temperature (°C)											
		Secondary Forest *			Lower Montane Forest			Tropical Rain Forest			Dry Evergreen Forest		
Seasons	Tree levels	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average
Hot season	Canopy	-	-	-	28.5	18.0	21.9	33.7	18.0	22.5	31.7	19.5	24.6
	Mid-trunk	31.9	19.5	24.4	-	-	-	-	-	-	-	-	-
	Base	-	-	-	29.1	17.4	21.3	31.9	17.4	22.2	29.6	17.4	23.1
Rainy season	Canopy	-	-	-	25.4	17.1	20.3	28.5	18.2	22.4	28.7	19.0	23.3
	Mid-trunk	29.0	17.2	23.1	-	-	-	-	-	-	-	-	-
	Base	-	-	-	24.0	18.4	20.8	27.6	18.2	22.1	27.9	18.6	22.6
Cool season	Canopy	-	-	-	25.1	12.0	18.5	30.4	11.2	20.4	30.4	12.5	20.0
	Mid-trunk	29.5	14.6	22.7	-	-	-	-	-	-	-	-	-
	Base	-	-	-	24.3	12.3	18.3	28.8	11.1	19.5	28.2	10.7	18.2

### ***Relative Humidity***

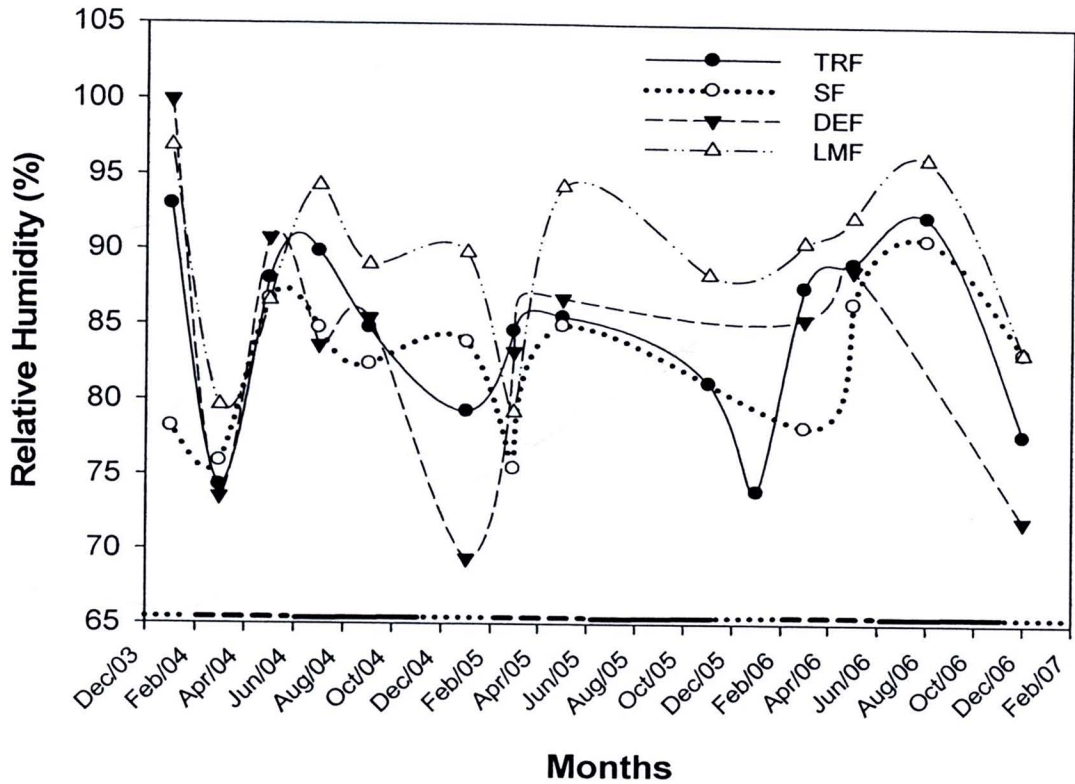
Relative humidity of various ecosystems during three years fluctuated among seasons as showed in Figure 26 and Table 6. Amounts of atmospheric moisture during the day were categorized into three phases based on its effects on metabolism of lichen as showed in Table 7.

***Lower Montane Forest.*** Averaged relative humidity during three year was 89%, which was higher than other forests (see Figure 26). Table 6 showed that humidity at the canopy in rainy season was closed to saturated, with RH averaged as high as 94.4%. RH in all seasons at every level was over 80%. Average humidity in rainy season never dropped below 90%. Nevertheless, humidity as low as 54-57% were occasionally recorded in hot season at canopy and tree base and cool season at the canopy.

***Tropical Rain Forest.*** This forest exposed to 84% average relative humidity during three years of observation. It was the second highest humid condition only second to LMF (see Figure 26). Relative humidity averaged over 80% in every season at every level, except cool season at the canopy which was 74%. Temperature fluctuation was similar to LMF. The maximum value of 100% was recorded in hot season at the canopy because fogs occurred (see Table 6). RH as low as 26-39 % were occasionally observed in cool season at canopy and tree base. The highest average relative humidity was observed at tree base in rainy season. Table 7 showed that during metabolic active period duration of high humidity, over 80%, occurred longer in hot season than rainy season.

***Dry Evergreen Forest.*** This area had average relative humidity about 83% during three years. Seasonal pattern was similar to TRF and LMF (see Figure 26). The highest maximum relative humidity as much as 98.6% was recorded at base tree in hot season, while the lowest of minimum value was 42.7% noted at canopy in cool season (see Table 6). The highest average relative humidity of 87.2% was observed at base trees in rainy season. Table 7 showed that humidity higher than 80% occurred for longer periods in hot season than rainy season.

***Secondary Forest.*** Average relative humidity of 82% was recorded in this forest, which was lower than the other areas (see Figure 26). Table 6 showed that the maximum relative humidity of 100% occurred in cool season, with evidence of fogs, whilst the minimum of 47% occurred in hot season. The highest and the lowest average humidities were 86 and 78% recorded in rainy season and hot season respectively. Table 7 reveals that metabolic active period of lichens, required humidity higher than 80%, occurred more than 75% and 60% of the daily period in rainy season and cool season respectively. By contrast, humidity lower than 80% occurred about 50% of the day in hot season.



**Figure 26** Seasonal fluctuation of relative humidity at lichen habitats in various ecosystems.

*Note.* From researcher; measurements were recorded during February 2004 to January 2007 at KYNP. ( ..... Cool season, - - - Hot season and ——— Rainy season)

**Table 6**

*Relative Humidity Along Vertical Strata of the Trees in Various Seasons and Forest Types at KYNP*

Seasons	Relative Humidity (%)														
	Microclimate			Secondary Forest *			Lower Montane Forest			Tropical Rain Forest			Dry Evergreen Forest		
Tree levels	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average
<b>Hot season</b>															
Canopy	-	-	-	96.1	54.1	83.5	100.4	40.1	83.3	95.1	46.3	83.2			
Mid-trunk	95.4	47.1	78.3	-	-	-	-	-	-	-	-	-	-	-	-
Base	-	-	-	97.3	57.2	85.2	97.3	45.0	88.4	98.6	48.3	86.5			
<b>Rainy season</b>															
Canopy	-	-	-	99.6	61.3	91.4	98.4	55.8	84.0	95.4	58.0	84.3			
Mid-trunk	97.8	47.5	86.3	-	-	-	-	-	-	-	-	-	-	-	-
Base	-	-	-	99.1	83.5	94.4	98.1	61.5	88.4	95.9	64.4	87.2			
<b>Cool season</b>															
Canopy	-	-	-	99.0	57.7	86.4	97.4	25.9	73.9	93.2	42.7	64.0			
Mid-trunk	100	50.2	81.6	-	-	-	-	-	-	-	-	-	-	-	-
Base	-	-	-	98.6	61.4	87.9	97.1	39.1	80.1	94.6	48.6	77.4			

**Table 7**

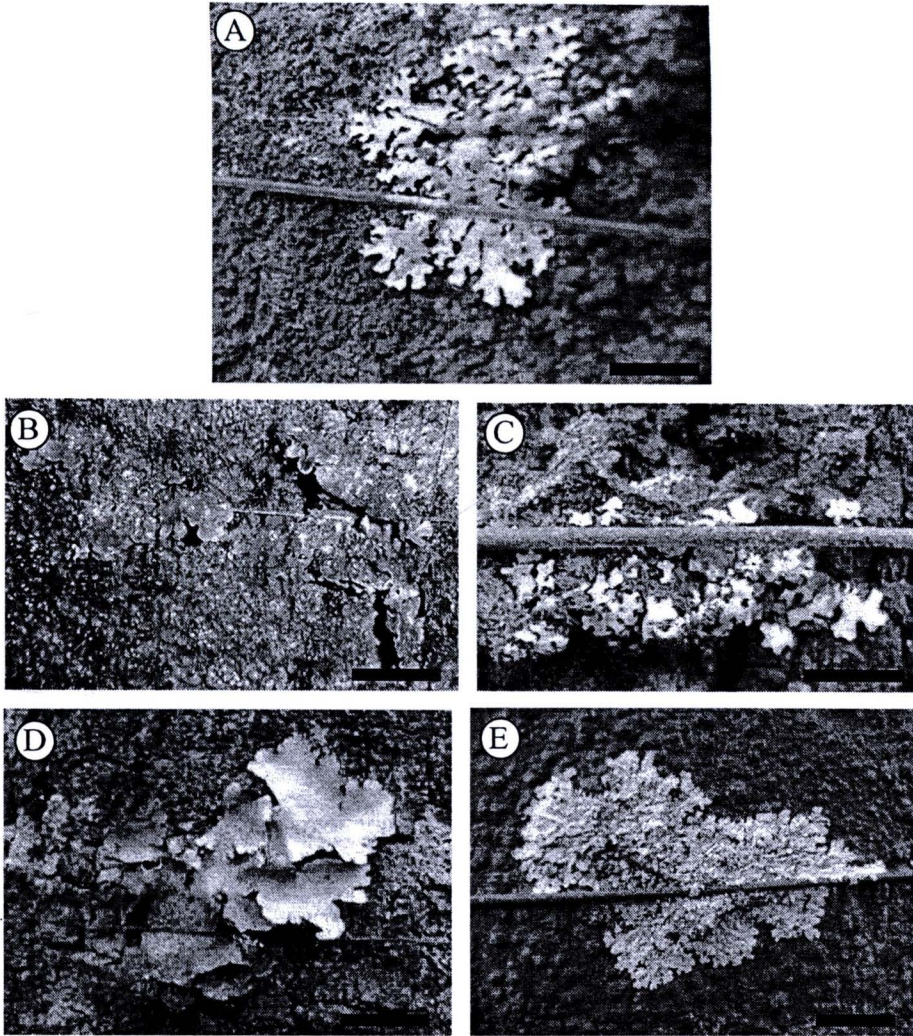
*Proportion of Time During the Day (24 hours) Which Different Levels of Relative Humidity were Observed Along Vertical Strata of the Trees in Various Seasons and Forest Types at KYNP*

Seasons	Microclimate Percentage of times collected data above specific levels of relative humidity (%)														
	Secondary Forest			Lower Montane Forest			Tropical Rain Forest			Dry Evergreen Forest					
Tree levels	<80	80-90	>90	<80	80-90	>90	<80	80-90	>90	<80	80-90	>90	<80	80-90	>90
<b>Hot season</b>															
Canopy	-	-	-	45.1	22.5	32.4	31.3	48.5	20.1	32.4	19.3	48.2	-	-	-
Mid-trunk	49.3	23.5	27.2	-	-	-	-	-	-	-	-	-	-	-	-
Base	-	-	-	31.2	28.4	40.4	17.6	19.9	62.5	23.4	15.9	60.7	-	-	-
<b>Rainy season</b>															
Canopy	-	-	-	6.4	16.8	76.8	37.6	35.3	27.1	35.2	26.4	38.4	-	-	-
Mid-trunk	23.9	19.6	56.5	-	-	-	-	-	-	-	-	-	-	-	-
Base	-	-	-	0.0	12.2	87.8	18.7	25.7	55.6	21.3	23.5	55.2	-	-	-
<b>Cool season</b>															
Canopy	-	-	-	29.3	38.7	32.0	51.5	29.6	18.9	89.2	7.4	3.3	-	-	-
Mid-trunk	38.0	17.4	44.6	-	-	-	-	-	-	-	-	-	-	-	-
Base	-	-	-	19.8	45.3	35.0	39.0	20.4	40.6	45.5	37.6	16.8	-	-	-

## Survival and Growth of Site-Specific Species Transplanted to Other Ecosystems

The five species of lichens comprising of *Dirinaria picta*, *Parmotrema rubromarginatum*, *Pseudocyphellaria argyracea*, *Relicina abstrusa* and *Relicina subconnivens* found only in warm habitats at TRF, DEF and SF were transplanted to cooler areas at LMF (see Figure 27). Four species grew in cool site at LMF including *Heterodermia lepidota*, *Hypotrachyna kingii*, *Hypotrachyna osseoalba* and *Parmelinella chozoubae* were transplanted to the warmer areas (see Figure 28). Survival and growth of the transplanted thallus fragments in these ecosystems were examined during June 2005 to December 2008.

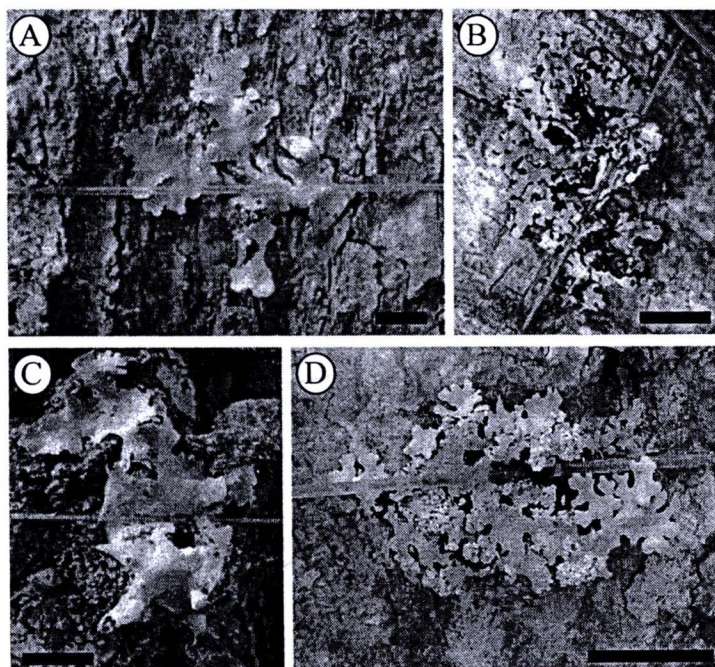




**Figure 27** Survived thalli of the lichens in the cool area transplanted from the warm areas at KYNP.

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*Note.* From researcher; *Relicina abstrusa* collected from TRF (A)  
*Pseudocyphellaria argyracea*–TRF (B), *Relicina subconnivens*–TRF (C),  
*Parmotrema rubromarginatum*–SF (D) *Dirinaria picta*–SF (E). The cool area was LMF. (Scale bar A, C and E = 0.5 mm; B and D = 1 cm)



**Figure 28** Survived thalli of the lichens in the warm areas (TRF, DEF and SF) transplanted from the cool area (LMF) at KYNP.

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*Note.* From researcher; *Hypotrachyna kingii* (A), *Heterodermia lepidota* (B), *Parmelinella chozoubae* (C) and *Hypotrachyna osseoalba* (D). (Scale bar = 0.5 mm)

### ***Survival of Thallus Fragment of Site-Specific Species Transplanted to Other Ecosystems***

The lichens that only found inhabited the warm areas at SF, DEF and TRF could survive in cool site (LMF) after transplantation better than those grew specifically in the cool site and transplanted to the warm sites (see Figure 30A, B, C and D).

Despite large numbers of thalli from the cool site died with in 2 months after transplantation to DEF and TRF, but those in the SF had the highest proportion of survivors.

After six months of transplantation, the highest percentage of survived thalli as much as 81% was observed in SF, whereas lower proportions of survived thalli were noted from LMF, DEF and TRF accounted for 73, 71 and 60% respectively (see Figure 29).

Between fifteen to thirty months of transplantation the survived thalli in the SF decline rapidly, as well as those in the DEF and TRF. The proportions of survived thalli accounted for 7-20% in these sites. On the other hand, those in the LMF had the highest proportion of survived thalli accounted for as much as 20-68% (see Figure 29).

At the end of observation period, forty three months after transplantation, the highest proportion of survived thalli was observed in the LMF accounting for 40%, and lower in SF noted for 19%. The DEF and TRF supported small proportions of survived thalli (see Figure 29).

Among the warm inhabitant species that were transplanted to the cool site, *R. abstrusa* had the highest proportion of survived thalli accounting for as

much as 67 % and subsequently lower in *P. argyracea*, *P. rubromarginatum*, *D. picta* and *R. subconnivens* recording for 51, 37, 25 and 20% respectively (see Table 8). All together made up an average of 40% of survived thalli.

By contrast, the cool inhabited species that were transplanted to the warm sites had remaining survived thalli as low as 9%. Among these, *H. kingii* has highest number of survivors accounting for 15% with the largest contribution of 23% from SF (see also Figure 29B). The lowest thallus survivor of about 6-8% was observed from *P. chozoubae*, *H. lepidota* and *H. ossealba*. However, *P. chozoubae* and *H. lepidota* transplanted to TRF and DEF. It is important to note that the last species could not survive in DEF (see Figure 29).

Large number the thallus fragments had symptom of necrosis, brown thalli, after transplantation. It probably caused by unfavorable microhabitat of the sites Figure 30A. In addition, insect and invertebrate infestations were observed on the transplanted thalli in almost every ecosystem (see Figure 30B and C). These were the main causes of thallus death after transplantation.



**Table 8***Thallus Survival of Site-Specific Species of Lichens During 43 Months of Transplantation to Other Ecosystems*

Species	No. of months					
	1 (Jun05)	6 (Nov06)	13 (Jun07)	21 (Feb07)	31 (Dce07)	43 (Dec08)
% survived thalli of warm species transplanted to cool site						
<i>R. abstrusa</i>	100.0	86.7	nd	nd	71.7	66.7
<i>P. argyracea</i>	100.0	77.1	77.1	77.1	65.7	51.4
<i>P. rubromarginatum</i>	100.0	78.9	66.7	56.7	45.0	36.7
<i>D. picta</i>	100.0	65.6	62.7	45.0	36.7	25.3
<i>R. subconnivens</i>	100.0	57.5	52.2	32.2	28.9	18.9
<i>Mean</i>	100	73.2	64.7	52.8	49.6	39.8
% survived thalli of cool species transplanted to warm sites						
<i>H. kingii</i>	100.0	74.9	55.6	nd	17.4	15.3
<i>H. osseoalba</i>	100.0	60.8	34.7	nd	10.9	7.7
<i>H. lepidota</i>	100.0	67.7	37.1	nd	12.3	7.1
<i>P. chozoubae</i>	100.0	78.9	57.3	nd	9.0	6.0
<i>Mean</i>	100	70.6	46.2		12.4	9.0

*Note.* nd = no data.



**Figure 30** Death and damaging thallus fragments of site-specific species of lichens after transplanted to other ecosystems.

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*Note.* From researcher; necrosis of thallus found at canopies in TRF and SF (A) and thalli infested by insect and invertebrate observed in all ecosystems (B and C). (scale bar = 1cm)

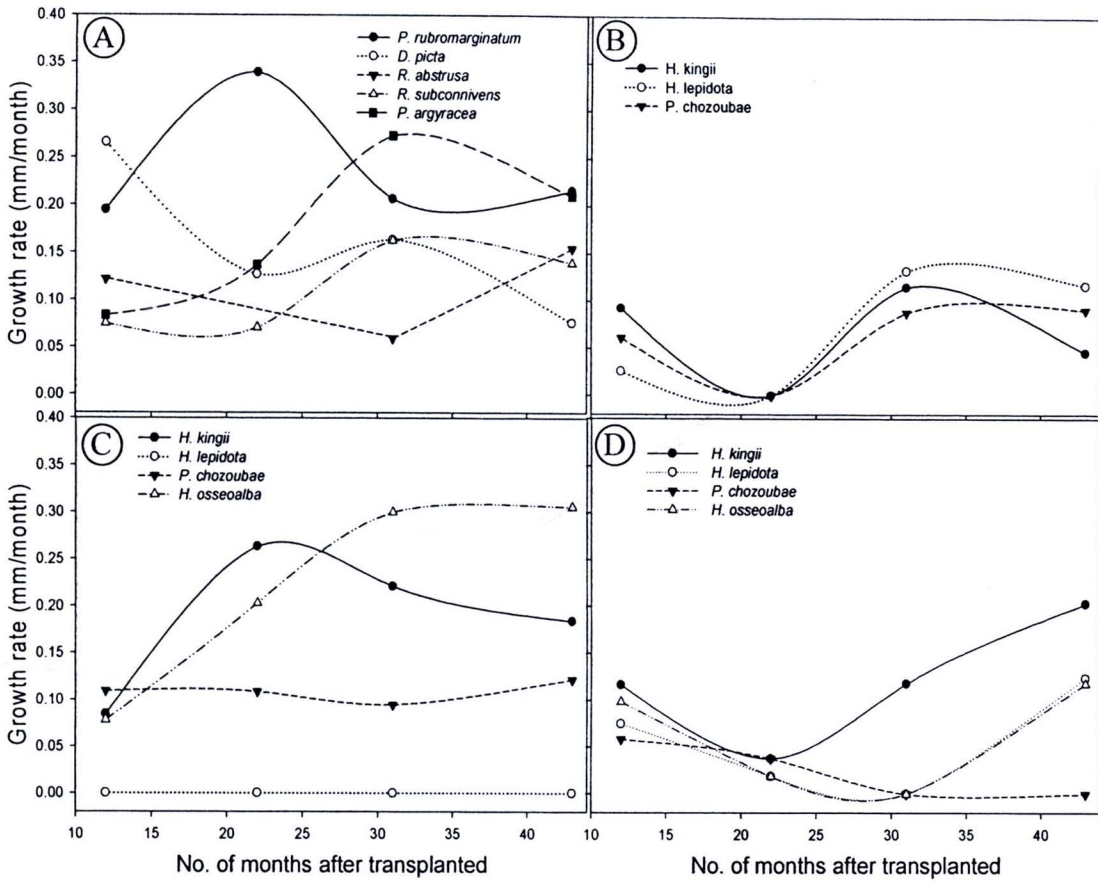
### ***Growth Rate of Site-Specific Species Transplanted to Other Ecosystems***

The survived thallus fragments, as much as 40%, of five species transplanted to the cool LMF from warm sites had fluctuated growth rates during forty three months of observation (see Figure 31A). At the end of observation period, slight increasing trend of growth rates were observed from *P. rubromarginatum*, *R. subconnivens* and *R. abstrusa*, while declining trend were noted from *P. argyracea* and *D. picta* (see Figure 31A).

During the same period, nine percent of thallus fragments of the four species transplanted to the warm sites at SF, TRF and DEF from the cool area survived and grew with less fluctuated growth rates Figure 31B, C and D. At the end of observation period survived thalli of *H. kingii* and *H. lepidota* in SF had declined growth rates, whereas *P. chozoubae* remained its constant growth in this forest. By contrast, *H. kingii* showed increasing trend of high growth rate in TRF, along with *H. lepidota* and *H. osseoalba*, whilst *P. chozoubae* had constant low growth rate.

Growth rates of all species transplanted to the cool LMF from the warm sites averaged 0.16 mm/month. The maximum of 0.62 mm/month were recorded from *P. rubromarginatum* and the minimum of 0.125 mm/month noted from *R. subconnivens*. On the other hand, four species transplanted to the warm sites from the cool area had averaged growth rate as low as 0.09 mm/month. The maximum growth rates of 0.39 mm/month were found from *P. chozoubae* and *H. lepidota* in SF, whereas the later species is unable to grow in DEF (see Table 9).

Average growth rates of each species that survived after transplantation to different habitats were shown in Figure 32. The highest growth rate of 2.6 mm/yr was observed from *P. rubromarginatum* transplanted to the cooler area, and subsequently lower in *P. argyracea*, *D. picta* *R. abstrusa* and *R. subconnivens* with rates of 2.1, 1.7, 1.34 and 1.34 mm/yr respectively. In comparison, growth rates of species transplanted to warm sites comprising of *H. osseoalba*, *H. kingii*, *H. lepidota* and *P. chozoubae* averaged 1.8, 1.5, 1.3 and 1 mm/yr respectively (see Figure 32).



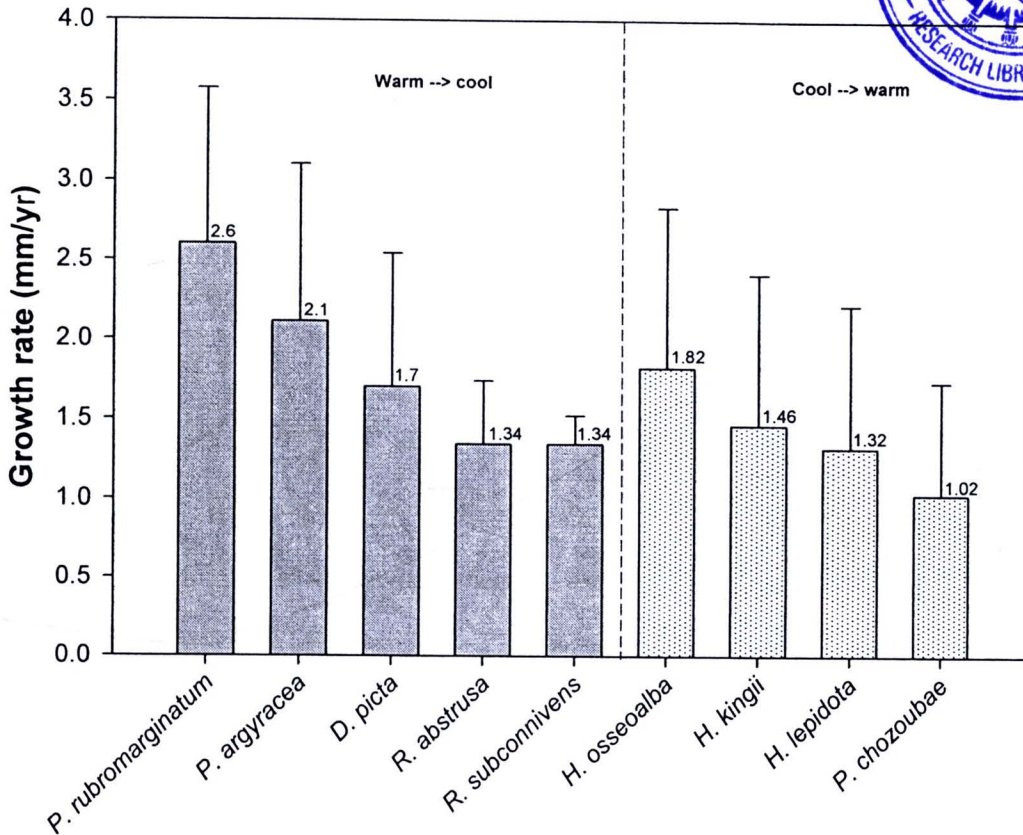
**Figure 31** Growth rates of thallus fragments of nine species of lichens transplanted to ecosystems differed from their original habitats.

*Note.* From researcher; lichens from warm sites transplanted to a cool LMF (A), lichen from a cool site transplanted to three warm sites at SF (B), TRF (D) and DEF (D). Growth rates were measured at 11, 22, 31 and 43 months after transplanted.

**Table 9**

*Maximum, Minimum and Average Growth Rate of Thallus Fragment of Site-Specific Species Transplanted to Various Ecosystems*

Transplanted Species	sites	Growth rate (mm/month)			
		max	min	average	± SD
Warmer species transplanted to cool areas					
<i>P. rubromarginatum</i>	LMF	0.864	-0.779	0.239	0.073
<i>P. argyracea</i>	LMF	0.422	-1.14	0.176	0.080
<i>D. picta</i>	LMF	0.650	-0.478	0.142	0.070
<i>R. abstrusa</i>	LMF	0.308	-0.306	0.112	0.049
<i>R. subconnivens</i>	LMF	0.450	-0.400	0.112	0.045
Mean		-	-	0.161	-
Cooler species transplanted to warm areas					
<i>H. osseoalba</i>	DEF	0.392	-0.303	0.155	0.138
	TRF	0.206	-0.850	0.073	0.063
<i>H. kingii</i>	DEF	0.456	-0.810	0.146	0.104
	SF	0.252	-0.735	0.094	0.059
	TRF	0.442	-1.138	0.102	0.097
<i>P. chouzoubae</i>	DEF	0.320	-0.451	0.075	0.057
	SF	0.385	-0.801	0.093	0.070
	TRF	0.167	-1.317	0.026	0.036
<i>H. lepidota</i>	DEF	0	-0.080	-	-
	SF	0.385	-0.762	0.122	0.078
	TRF	0.233	-1.250	0.034	0.050
Mean		-	-	0.094	-



**Figure 32** Average growth rates of site-specific species after transplanted to different ecosystems.

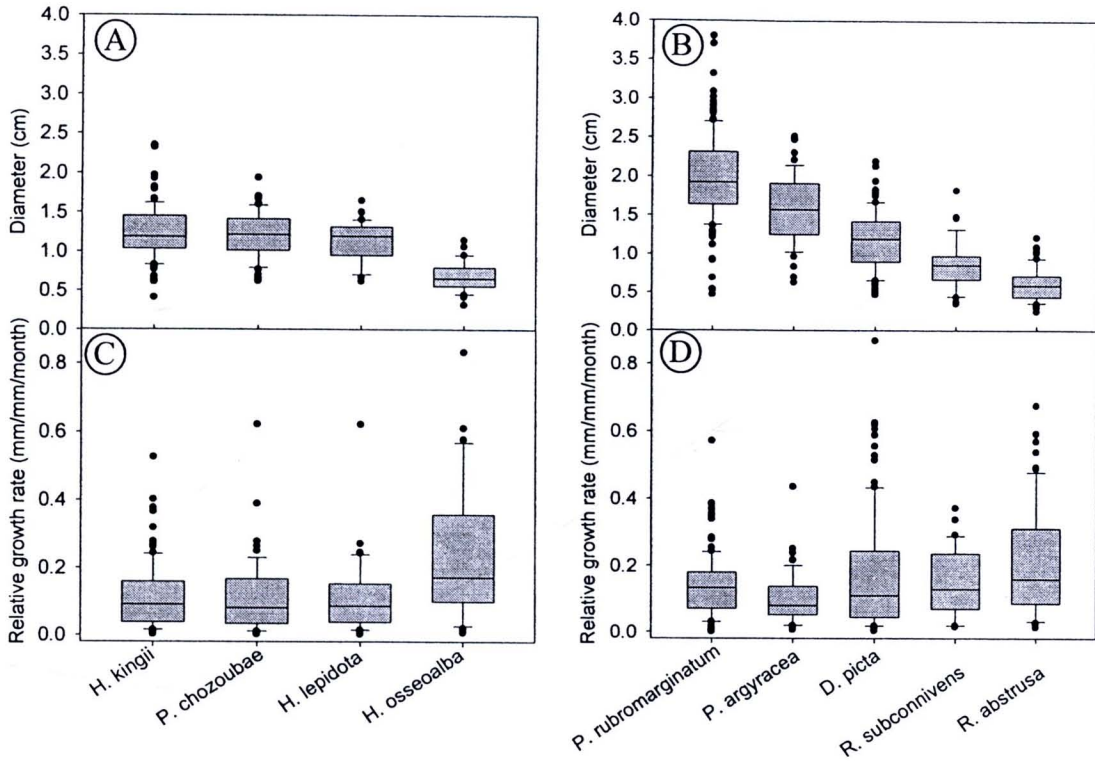
*Note.* From researcher; five species transplanted to a cool site from warm sites (shade bar), and four species transplanted to warm sites from a cool site (dot bar). Significant difference between warmer and cooler sites is  $P=0.001$ .

### *Relative Growth Rate (RGR) of Site Species Species*

“Relative growth rate” is used to characterize expansion of thallus diameter of lichen per unit of original diameter per unit of time (mm/mm/month). It is useful to compare growth of transplanted thalli which start with different sizes.

The lichen *P. argyracea*, *R. abstruse* and *D. picta*, transplanted to the cool area, and *H. kingii*, *P. chozoubae*, *H. lepidota* and *H. osseoalba* transferred to the warm areas had declined relative growth rates (see Appendix C). By contrast, *R. subconnivens*, which were transplanted to cooler area, showed increasing relative growth rate, whilst *P. rubromarginatum* showed stable relative growth rate.

Rrelationship between relative growth rates and thallus diameters of site-specific species transplanted to other ecosystems, either cool or warm areas were shown in Figure 33. The large thalli of cooler species (*H. kingii*, *P. chozoubae* and *H. lepidota*) showed lower relative growth rate than *H. osseoalba* which has smaller thalli (see Figure 33A and C). Similar results were found in the warmer species (*P. rubromarginatum*, *P. argyracea*, *D. picta*, *R. subconnivens* and *R. abstrusa*). The highest relative growth rate were measured from *R. abstrusa*, which has the smallest thallus size (see Figure 33B and D). Conversely, the largest thallus *P. rubromarginatum* demonstrated low relative growth rate.



**Figure 33** Relative growth rate of site-specific species transplanted to various ecosystem.

*Note.* From researcher; box plots shows the 25-75 percentiles (box), the median (horizontal line), and the 10th and 90th percentiles (arms). Thallus sizes of cool species transplanted to warm areas (A) and warm species transplanted to a cool area (B), and relative growth rate of cool species transplanted to warm areas (C) and warm species transplanted to a cool area (D).

## **Survival and Growth of Vegetative Propagule Transplanted to Various Ecosystem**

Vegetative propagules such as thallus fragments and isidia of *P. tinctorum* and soredia of *P. praesorediosum* that are commonly found in secondary forest were collected for transplantation. Adaptation to new sites of thallus fragments were examined by growth and survival, while isidia and soredia were determined by germination and survival.

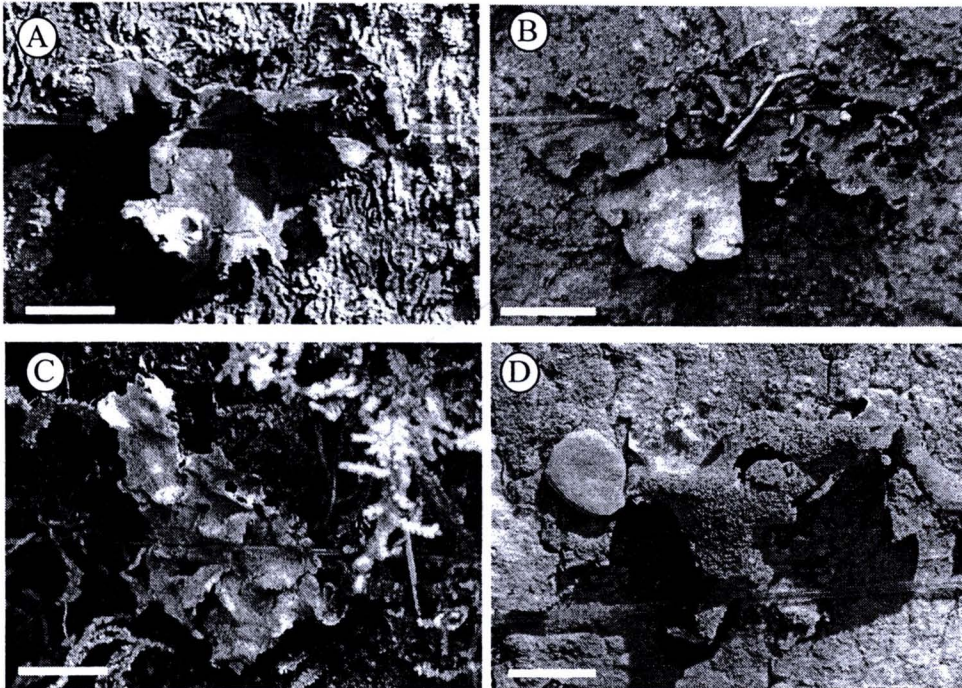
### ***Thallus Fragments***

#### ***Survival of Thallus Fragments***

***Survival in various ecosystems.*** Changing thallus color from grey-green to red-brown were frequently seen on lichen materials after 2-10 months of transplantation (see Figure 34A and B). This could be recognized as death or unsuccessful adaptation to new sites. Thallus fragments of *P. tinctorum* that unable to grow produced numerous isidia on upper surface (see Figure 34D). This vegetative propagule is a mean for dispersion in natural habitats.

Sixty-four months after transplantation, the highest number of survived thallus accounting for 37.5% was observed in LMF, and subsequently lower in SF, DEF and TRF consisting of 28.3, 6.7, and 6.7% respectively (see

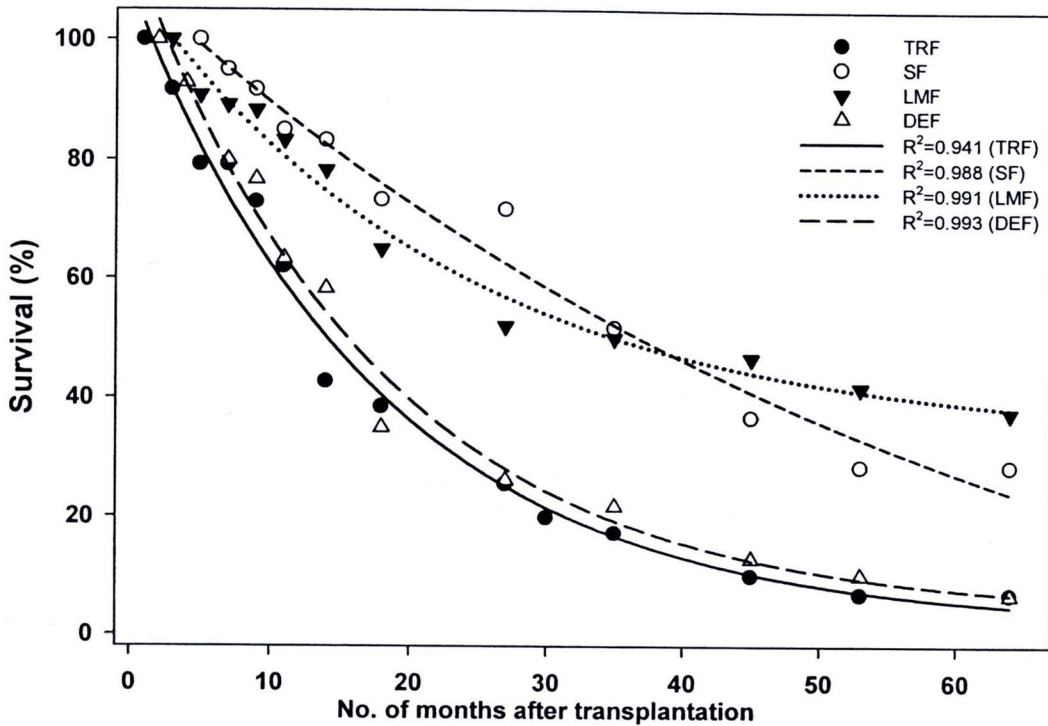
Figure 35 and Table 10). LMF and SF had larger proportion of survived thalli than those observed from TRF and DEF.



*Figure 34* Deteriorated and intact thallus fragments of *P. tinctorum* after transplantation.

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*Note.* From researcher; thallus death in DEF (A), TRF (B) and LMF (C) after 2 months of transplantation, and survived thallus produced a small lobe and numerous isidia on upper surface (D). (scale bar = 1cm)



**Figure 35** Survival trend of thallus fragments of lichens after transplantation to forest types.

*Note.* From researcher; thallus survivors were observed during 64 months of transplantation (Aug 2003 to Dec 2008) in ● = Tropical rain forest (TRF), ○ = Secondary forest (SF), Δ = Dry evergreen forest (DEF) and ▼ = Lower montane forest (LMF).  $r^2$  of trend line in each ecosystems were calculated.

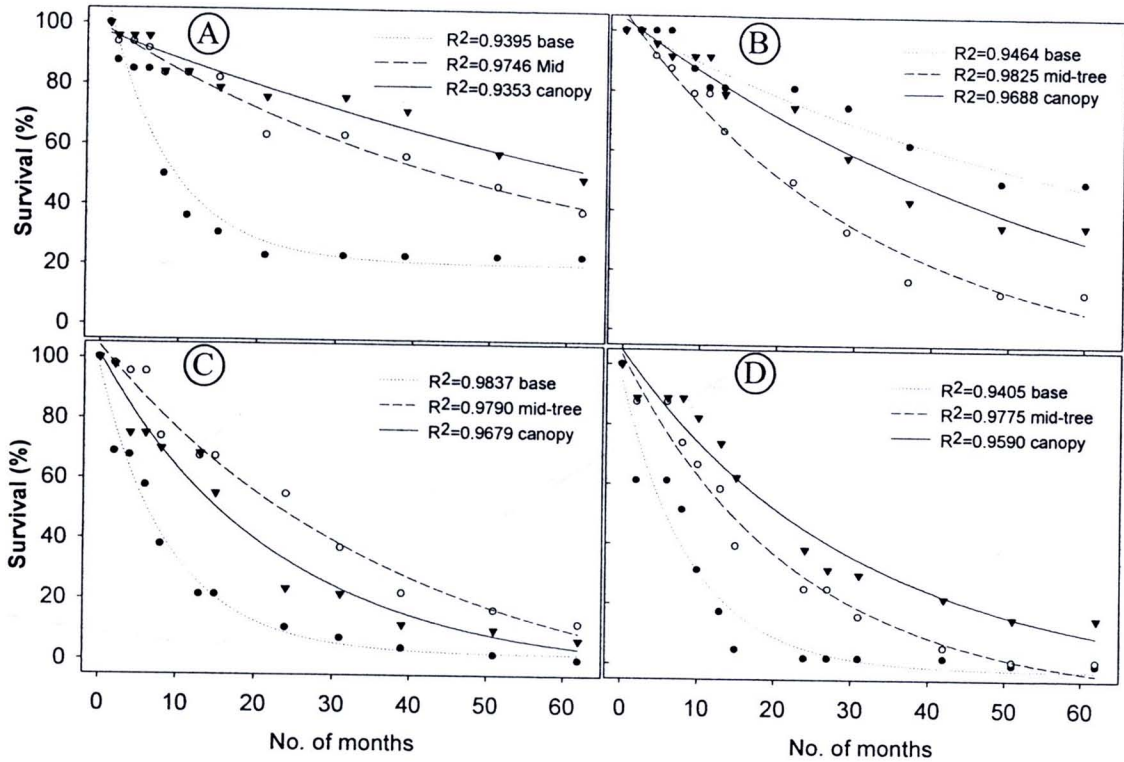
**Thallus survival along tree trunks.** Thallus fragments of *P. tinctorun* transplanted to tree base, mid trunk and canopy at four different types of forests had different numbers of survived thalli after 64 months of investigation (see Figure 36).

LMF: The transplanted material in Lower Montane Forest (LMF) had the greatest number of survivors at the canopy, and subsequently lower at

mid-trunks and tree base accounting for 49, 38 and 23% respectively (see Figure 36A). Nevertheless, those transplanted to tree base died substantially within 18 months after transplantation.

SF: Interestingly, thallus fragments transplanted to the Secondary Forest (SF) showed different results. The highest proportion of survived thalli was found at tree base after 64 months of transplantation, accounting for 50%, and subsequently lower at canopy and mid trunk noted for 35% and 13% respectively (see Figure 36B). Thallus mortality after transplantation was lower than the other forests.

DEF and TRF: Number of survived thalli in Dry Evergreen Forest (DEF) and Tropical Rain Forest (TRF) were remarkably low. The highest thallus survivors was only 16% occurred at mid-trunks in DEF (see Figure 36C), and canopy of TRF (see Figure 36D). Tree base of DEF could not support any transplanted materials.



**Figure 36** Proportion of survived thalli of *P. tinctorum* at three levels of tree trunks in various ecosystems.

*Note.* From researcher; thallus survival during 64 months (August 2003 to December 2008) in Lower montane rain forest (A) Secondary forest (B) Dry evergreen forest (C) and Tropical rain forest (D). ▼ = canopy, ○ = Mid-trunk and ● = Base trees.

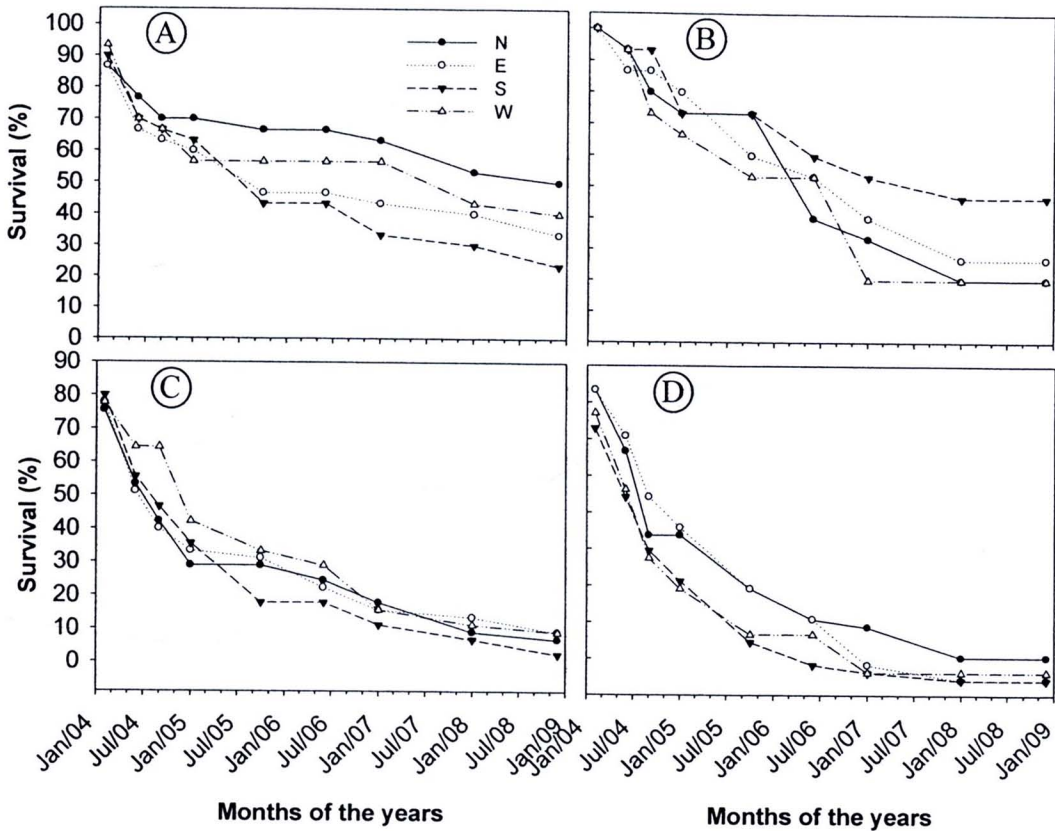
### ***Effects of aspect orientation on thallus survival in various forests.***

The influences of illumination on aspects of tree trunk oriented to the sun on transplanted thallus fragments were observed during 64 months (see Figure 37). The highest number of thallus survivors was found on the North aspect of Lower Montane Forest (50%) and subsequently lower on the West, East and South accounted for 40, 33, and 23% respectively (see Figure 37A). In the

Secondary Forest, the highest proportion of survivors accounted for 47% was found on the South, and lesser substantially on the East, North and West noted for 26, 20 and 20% respectively (see Figure 37B).

The Dry Evergreen Forest and Tropical Rain Forest showed extremely low rate of thallus survivor ranged from 2-10 %. In the DEF, most transplanted thallus found on the East (9%), while 10 % of thallus survivors was found on the North aspect of TRF (see Figure 37C and D).

However, number of survived thalli declined continuously in all aspects from all ecosystems during the observation from February 2004 to December 2008. The highest proportion of survived thalli of 21.8% was observed on the North-facing, and subsequently lower at the South, the West and the East accounting for 19.1, 18.8 and 18.3% respectively (see Table 10).



**Figure 37** Survival of thallus fragments in various aspects of tree trunks in four ecosystems after transplantation.

*Note.* From researcher; thallus survivors during 64 months (Oct 2003 to Dec 2008) in Lower montane rain forest (A) Secondary forest (B) Dry evergreen forest (C) and Tropical rain forest (D). ● = North (N), ○ = East (E), ▼ = South (S) and Δ = West (W).

**Table 10**

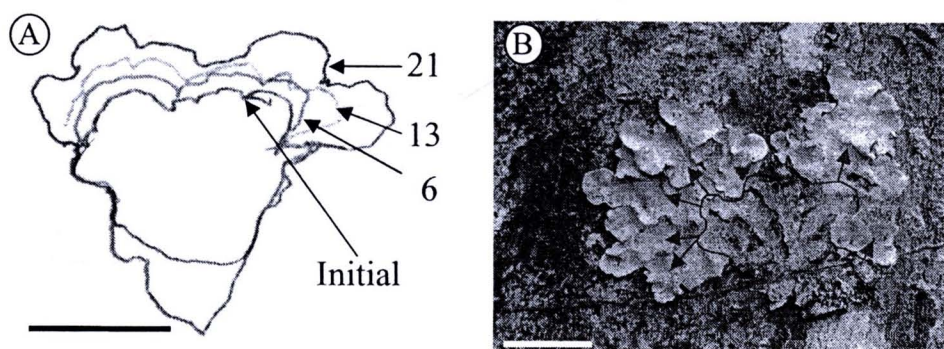
*Survival of Thallus Fragments of P. tinctorum After Transplanted on Four Aspects of Tree Trunks at Various Forest Types During Aug 2003 to Dec 2008*

Months	Survived thalli (%)			
	North*	East	South*	West
Feb-04	86.4	86.9	85.7	87.0
Jun-04	72.5	68.8	68.3	71.0
Sep-04	59.0	61.0	61.6	68.0
Jan-05	54.0	54.8	50.9	48.7
Oct-05	49.5	41.7	37.3	40.0
Jun-06	38.0	35.8	32.4	38.9
Jan-07	33.3	26.8	26.0	24.6
Jan-08	23.2	21.0	21.9	20.2
Dec-08	21.8	18.3	19.1	18.8

*Note.* From researcher; \* The North was significant different from the South, (P<0.01) by one-way ANOVA.

### *Growth Rate of Thallus*

The expansions of thallus fragments of *P. tinctorum* after transplanted were measured to determined growth rate. In favorable environment thallus fragments established on new substrate, grew and produce new lobes (see Figure 38).



**Figure 38** Expansion of thallus fragment times after transplantation.

*Note.* From researcher; outlines of thallus of *P. tinctorum* after transplanted for 1, 6, 13 and 21 months (A), new lobes grew from thallus fragment (arrows) after transplanted to LMF for 62 months (B). (scale = 3 cm)

***Growth rate of thallus fragments in various ecosystems.*** The thallus fragments transplanted to various ecosystems had different growth capacity (see Table 11). The highest growth rate of individual thalli as much as 1.12 mm/month was recorded at LMF after rainy season (October 2005), and subsequently lower in SF, DEF and TRF accounted for 0.81, 0.58 and 0.5 mm/month respectively. However, the highest of average growth rate of 0.37 mm/month was observed in LMF, which was different from 0.23, 0.18, and

0.17 mm/month measured from SF, DEF and TRF respectively (see Table 11).

**Table 11**

*The Growth Rate of Thallus Fragment of P. tinctorum in Four Ecosystems during Sixty Months after Transplantation.*

No. of months after transplanted	Average growth rates (mm/month)			
	TRF	LMF	SF	DEF
11 (Jul-04)	0.157	0.333	0.208	0.218
18 (Jan-05)	0.254	0.338	0.207	0.263
21 (Sep-05)	-	-	0.382	-
27 (Oct-05)	0.225	0.464	-	0.269
33 (Apr-06)	-	-	0.113	-
34 (May-06)	0.048	-	-	0.205
42 (Jan-07)	-	-	0.259	0.117
45 (Apr-07)	0.118	0.253	-	-
53 (Jan-08)	0.143	0.429	0.142	0.033
64 (Dec-08)	0.209	0.402	0.307	0.173
mean	0.165	0.37*	0.232	0.177

*Note.* From researcher; \*  $P < 0.001$

***Influences of tree heights on growth rate.*** Growth rates of the transplanted thallus fragments varied among trees and forest types. Growth rates of the transplanted thalli in TRF and DEF were significantly different. Among the three host trees in TRF growth rate of lichens on each tree was

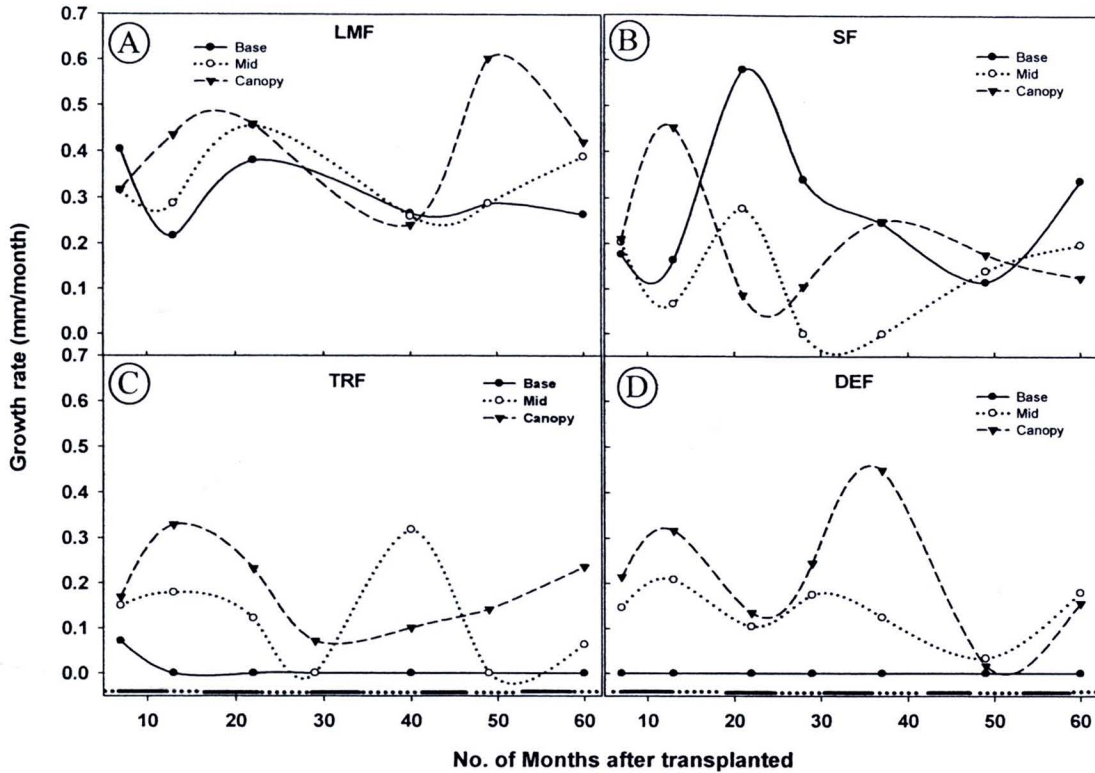
0.24, 0.11 and 0.14 mm/month, which were similarly those observed in other ecosystems.

Average growth rates of transplanted thallus fragments on three levels of tree trunks at four types of forest during February 2004 to December 2008 were shown in Figure 39. The highest average growth rate of 0.24 mm/month was found at canopy, and lower at mid-trunk and tree base accounted for 0.21 and 0.19 mm/month.

The highest average growth rate of 0.34 mm/month was recorded at the canopy of Lower Montane Forest, with lower rates were observed at mid-trunk and tree base accounted for 0.29 and 0.28 respectively. The highest fluctuated growth rate was observed in rainy season (see Figure 39A).

Similarly pattern was observed in the Secondary Forest, the highest averaged growth rate of 0.23 mm/month occurred at canopy, and subsequently lower at tree base and mid-trunk accounted for 0.22 and 0.21 respectively (see Figure 39B). By contrast, growth rate of lichen in the Tropical rain forest was different, of which the highest growth rate of 0.19 mm/month was observed from mid-trunk, and lower at canopy and tree base accounted for 0.16 and 0.07 mm/month respectively (see Figure 39C).

The Dry Evergreen Forest had the highest growth rates of 0.23 mm/month at canopy and lower at mid-trunk noted for 0.15 mm/month. Those at tree base showed no growth, which indicated that this level was unsuitable for transplantation (see Figure 39D).



**Figure 39** Fluctuated of growth rates of *P. tinctorum* after transplanted on three levels of tree trunks in various ecosystems.

*Note.* From researcher; thallus growth rate during 62 months in Lower Montane Forest (A), Secondary Forest (B), Tropical Rain Forest (C), and Dry Evergreen Forest (D) (—) rainy season and (...) cool season and hot season.

**Growth rates on various aspects of tree trunks.** The *Lower Montane Forest* supported the highest growth rate of the transplanted lichens accounted for 0.37 mm/month (see Figure 40A). This was observed on the East aspects, whereas those on the South, the North and the West had rates of 0.31, 0.30 and 0.29 mm/month respectively (see Figure 35).

The *Secondary Forest* had the second highest growth rate of the transplanted thallus fragments averaged 0.25 mm/month observed on the

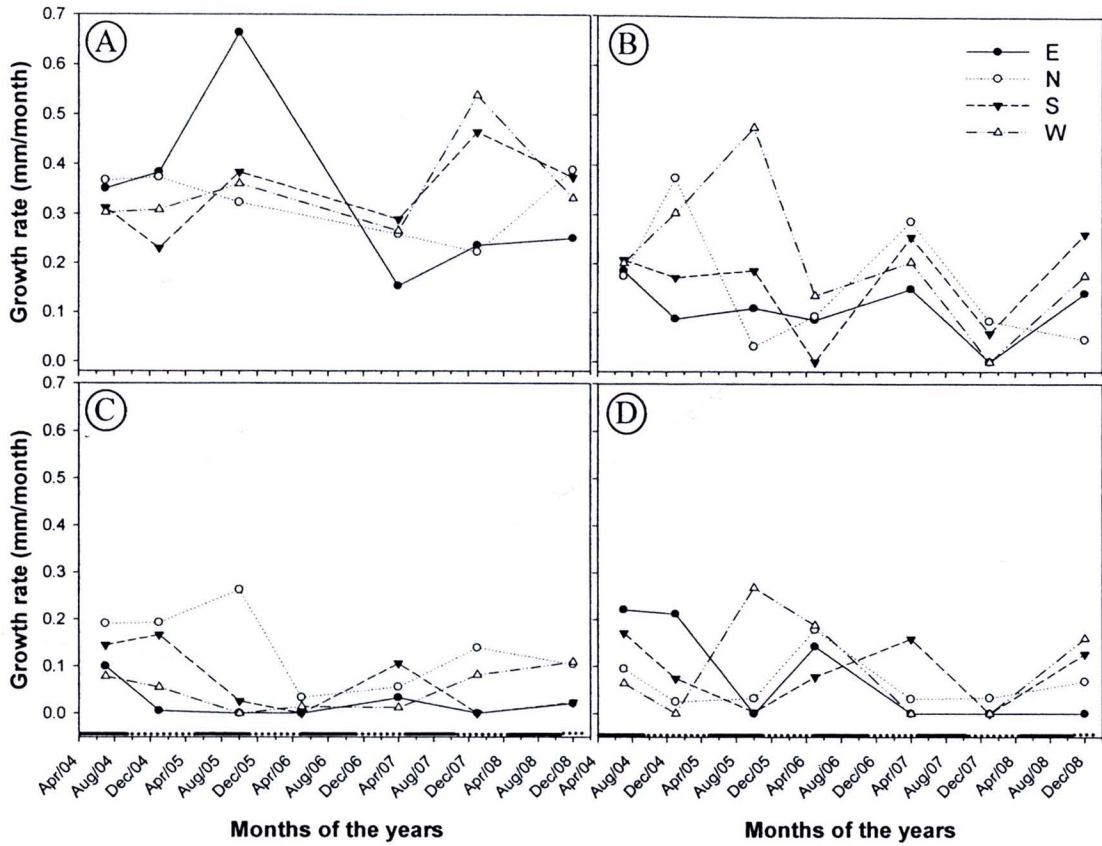
West. Those on the South, the East and the North aspects of trunks had growth rates 0.24, 0.19 and 0.185 mm/month respectively (see Figure 40B).

The dense ground vegetation of *Dry Evergreen Forest* had the highest growth rate of 0.28 mm/month on the East, and subsequently lower on the South, the West and the North with rates of 0.17, 0.15 and 0.14 mm/month respectively. (see Figure 40D)

Tropical Rain Forest had less different growth rates among the four aspects comparing with the other three forests (see Figure 40C). The highest growth rate in this forest was observed on the North noted for 0.21 mm/month), and subsequently lower on the South, the West and the East accounted for 0.16, 0.14 and 0.10 mm/month respectively.

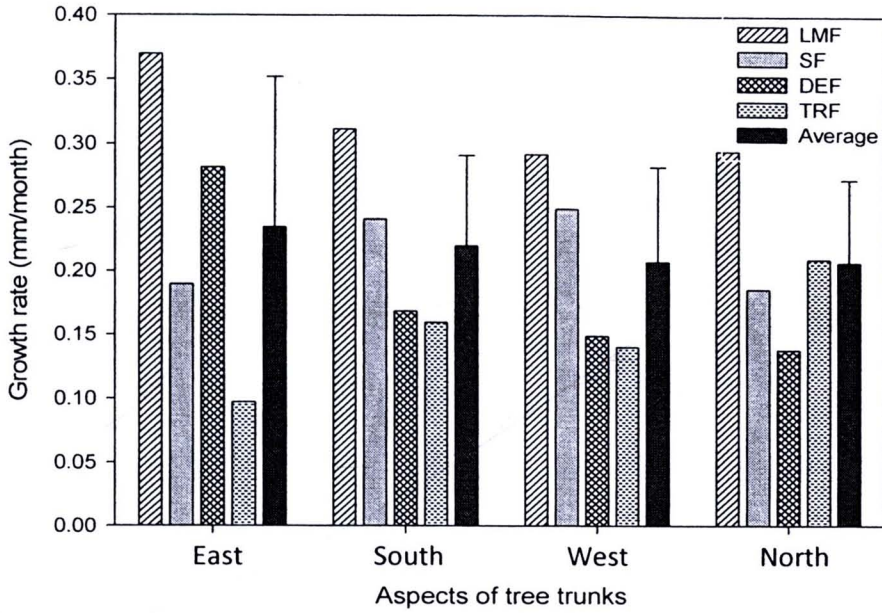
However, all four aspects of trees trunks showed no significant difference in growth rates. The highest of averaged growth rate of 0.24 mm/month were found on East, and subsequently on South, West and North accounted for 0.22, 0.21 and 0.21 respectively (see Figure 41). Nevertheless, significantly difference of growth rate on four aspects was particularly observed in TRF where the North was higher than other aspects ( $P < 0.01$ ).





**Figure 40** Variation in growth rates of thallus fragments of *P. tinctorum* after transplanted on four aspects of tree trunks at four ecosystems.

*Note.* From researcher; growth rate of surviving thalli on four aspects in Lower montane forest (A), Secondary forest (B), Tropical rain forest (C) and Dry evergreen forest (D). East (●), North (○), South (▼), West (Δ), and (...) Dry season) and (—) wet season).



**Figure 41** Growth rates of thallus fragments of *P. tinctorum* on four aspects of tree trunks after transplantation in four forests.

*Note.* From researcher; growth rate were measured after 62 months of transplantation (Dec 2003 to Dec 2008).

### *Vegetative Diaspores*

Isidia of *P. tinctorum* and soredia of *P. presorediosum* collected from secondary forest were transplanted to TRF, DEF, SF and LMF, they were adhered on Double-Sided Glue Tape (DSGT) and attached on trunks of host trees. After transplantation, diaspores germinated into tiny lobes of various sizes as showed in Figure 42 and 43.

#### *Germination of Vegetative Diaspores*

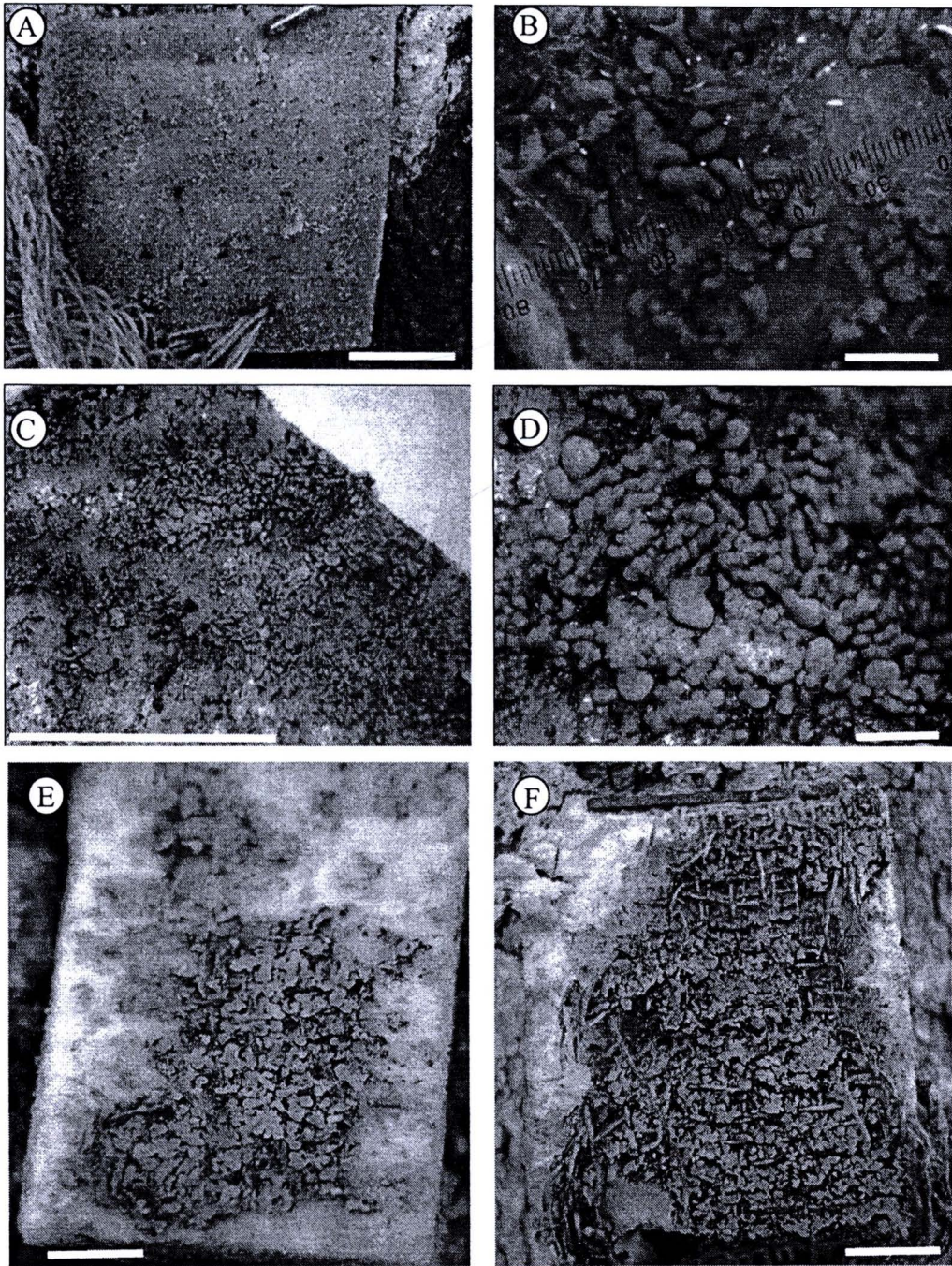
*Germination of diaspores in various ecosystems.* Six months after transplantation, small lobes were first observed from germinating isidia in LMF and TRF, while germination of soredia was unobservable in any forest. Twelve months after transplantation 63%, 56%, 9% and 6% of germinated isidia were observed in LMF, SF, TRF and DEF respectively (see Figure 44A). Only isidia in the LMF developed into small lobes.

Soredia developed into primodia, early development of lobe, without recognizable structure of lobe. Geminated soredia were observed at LMF, SF and accounting for TRF 51%, 9% and 0.5% respectively, however, without any of those found in DEF (see Figure 44B). The first lobe of soredia was recognized in the SF after twelve months of transplantation (see Figure 43C).

In general, soredia developed into larger lobes than isidia as showed in Figure 42F and 43F. The largest numbers of germinated isidia and soredia were observed in 10 and 15 months after transplantation, and declined thereafter (see Figure 44). After transplantation for twelve and twenty five

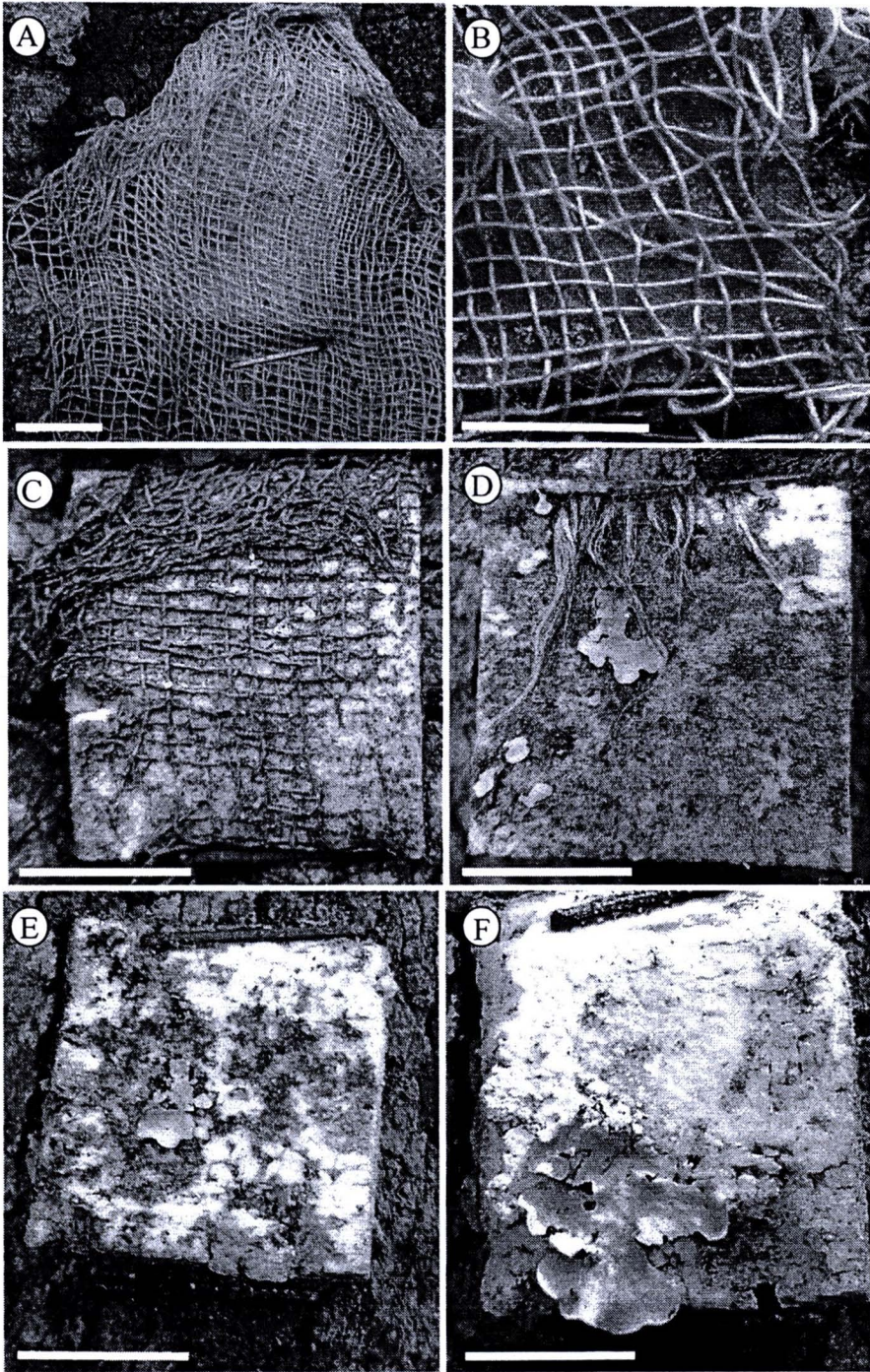
months, many diaspores were encroached by algae *Trentepohlia* sp. especially in the LMF (see Figure 45). It caused rapid-decline of the germinating diaspores in this forest. Obviously, both diaspores could not stay alive for long period of time in LMF (see Figure 44).

After twenty-five months, germinated isidia declined rapidly with proportion of survivors accounted for 52, 8 and 5% in the SF, TRF and DEF respectively, whilst, germinated soredia remained intact. Thirty-two months after transplanted, larger juvenile lobes of isidia were observed in all sites. Whereas, germination of both diaspores declined continuously due to insect grazing and invading by bryophyte as show in Figure 46A. After 32 to 62 months of transplantation, densely germinated isidia on DSGT remained, but without further development in size. However, partial degeneration was observed in SF. By contrast, germinating soredia could be developed into juvenile thalli more than isidia. After thirty-two months, the germinating isidia at the SF were collected and examined under the microscope (see Figure 46A). Cross section of the juvenile thalli found that stratification of the photobiont and mycobiont occurred with rhizines on the lower surface. These characterized heteromerous thallus of the foliose lichen (see Figure 46B). Sixty-two months after transplanted, the highest number of survivors, 9 and 8% of the germinated isidia and soredia were observed in SF. Whereas, those in DEF and TRF were only 1%, and completely wiped out in LMF.



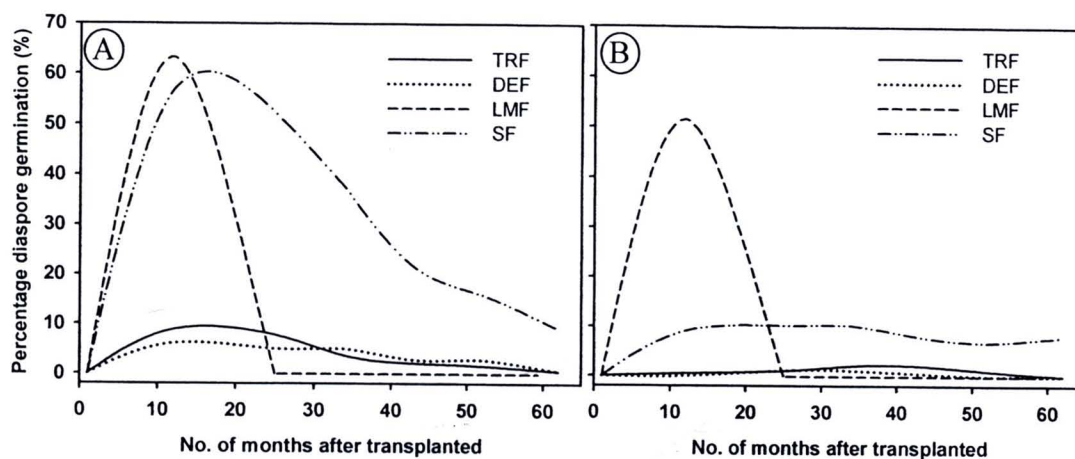
**Figure 42** Germinated isidia of *P. tinctorum* on DSGT.

*Note.* From researcher; Isidia germinated on DSGT in TRF after 6 months of transplantation (A, B), 12 months after transplanted in LMF (C, D), small lobe developed in 32 months after transplanted (E) and 60 months (F) in SF. (scale bars on figure A, C E and F = 5 mm and on figure B and D = 1 mm)



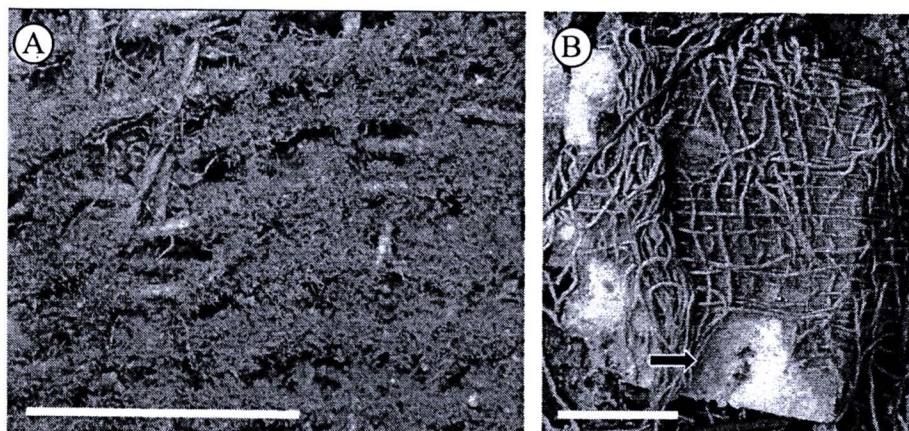
**Figure 43** Germinated soredia of *P. presorediosum* on DSGT.

*Note.* From researcher; After transplantation for 6 months (A), 12 months (B), developed juvenile lobes after 32 months (C and D), 45 months (E) and 60 months (F). (scale bars = 5 mm)



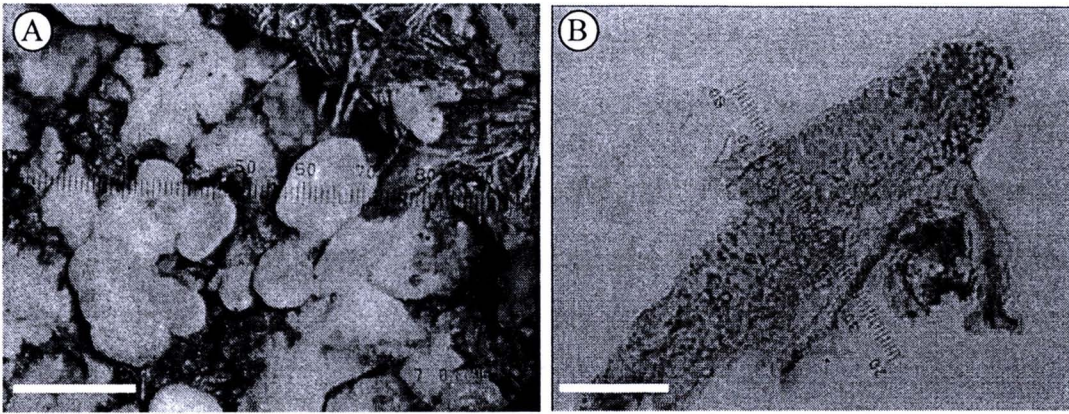
**Figure 44** Proportion of diaspores germination in various ecosystems.

*Note.* From researcher; germination of isidia (A) and soredia (B) in four ecosystems during 60 months after transplanted (April 2004 to December 2008).



**Figure 45** Death of germinating diaspores caused by algal encroachment and insect infestation.

*Note.* From researcher; *Trentepohlia* sp. grew covered cheese cloth covering DSGT in LMF after transplanted for 25 months (A). Arrow showed insect grazed DSGT during transplanted 62 months in SF (B). (scale bar = 1cm)



**Figure 46** Juvenile lobes developed from isidia of *P. tinctorum*.

*Note.* From Dec 2003 to July 2006, juvenile lobes on DSGT after 32 months of transplantation in SF (A) x-section of juvenile lobe showed heteromerous thallus, which photobiont and mycobiont stratified, and rhizine developed (B). (The scale bars, Figure A =1mm and B = 1 $\mu$ m)

#### ***Germination of diaspores along tree trunks.***

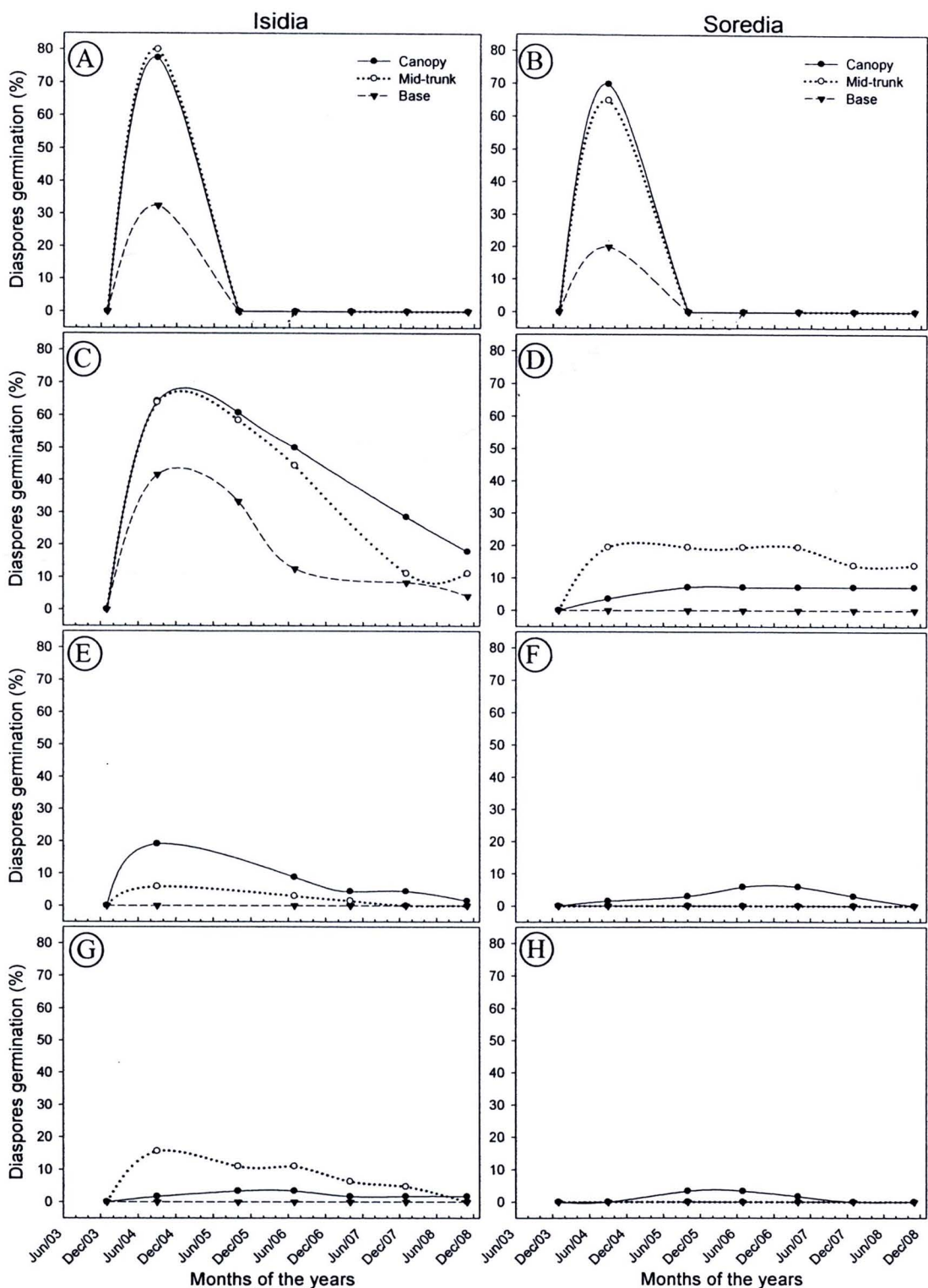
Lower Montane Forest: This forest had the highest germination of isidia accounted for 80% occurred at mid-trunks in 12 month of transplantation. Subsequently lower proportion were observed at canopy and base trees accounted for 67 and 33% respectively (see Figure 47A). At the same time, the highest soredia germination of 70% were observed at canopy, and subsequently lower at mid-trunks and base trees accounted for 65 and 20% respectively (see Figure 47B). Thereafter, survivors of both isidia and soredia were invaded by *Trentepohlia* sp. during 25 to 64 months of transplantation.

Secondary Forest: This forest had the highest isidia germination of 64% observed at canopy in 12 month of transplantation, and subsequently lower at mid-trunk and tree base with 64 and 42% respectively (see Figure

47C). By contrast, the highest soredia germination of 19% was found at mid-trunk, while 7% was observed at canopy. Notably, without germinated at trees base in 25 months after transplantation (see Figure 47D). The isidia had proportion of survivors at canopy, mid-trunk and base trees accounted for 17%, 11% and 4% respectively, while those of the soredia were 7%, 14% and 0% after 64 months of transplantation.

**Tropical Rain Forest:** The isidia in this forest had proportion of germination accounted for 19% and 6% observed at canopy and mid-trunks, and without germination at base trees after 12 month transplantation. Two percent of isidia at canopy could survive through 64 months of transplantation (see Figure 47E). Soredia could particularly germinated at canopy, however, with lesser proportion noted for 6% (see Figure 47F) during 34 to 43 months of transplantation. The germinated soredia were unable to live through 64 months after transplantation.

**Dry Evergreen Forest:** This forest had germinated isidia accounted for 16% and 3% observed at mid-trunk and canopy in 12 and 25 months of transplantation respectively (see Figure 47G). Two percent of isidia could survived at canopy after 64 month of transplantation. Soredia had the highest proportion germination accounted for 3% at canopy during 25 to 34 months of transplantation, while those at mid-trunk and tree base had no germination (see Figure 47H). In addition, none of the germinated soredia survived after 52 months of transplantation.



**Figure 47** Proportion of isidia and soredia germination in various tree levels.

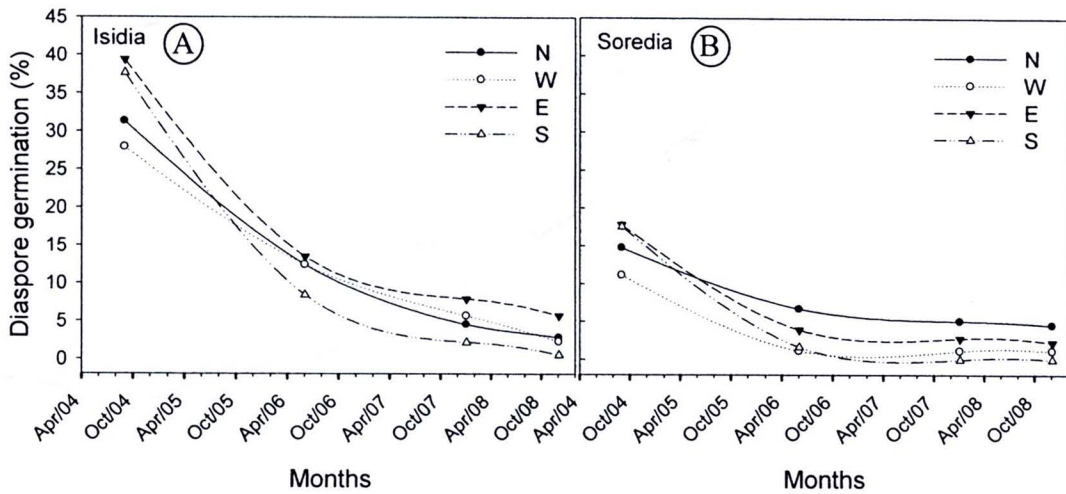
*Note.* From researcher; diaspores germination in Lower Montane Forest (A-B), Secondary Forest (C-D), Tropical Rain Forest (E-F) and Dry Evergreen Forest (G-H).

*Germination of diaspores on various aspects of trees trunk.* Ten months after transplantation of diaspores on four-aspect orientation of tree trunks, it was found that isidia and soredia had the highest germination and survived on the East aspect accounting for 39 and 18%. Germination of isidia on the West, North and South were 28, 31 and 38 respectively, whereas those from the soredia were 11, 15 and 18% (see Figure 48A). The highest germination of isidia on the East was observed throughout the investigation period of transplantation. After twenty-five months, large numbers of the transplanted diaspores disintegrated, however, with the highest survivors of soredia observed on the North accounting for 7% (see Figure 48B).

Forty-five months after transplantation, both germinating diaspores were demolished. The highest proportion of the germinating isidia was noted from the Eastern aspect accounting for only 8%, whereas those from the South, North and West were 2, 5 and 6% respectively. The germinated soredia had the highest survivor in the North accounted for 5% and subsequently lower in the South, West and East noted for 0, 1 and 3% respectively.

Sixty-two months after transplanted, the highest survivor of germinated isidia was examined from the East accounting for 6%, whereas those from the South, West and North were 0.5, 2 and 3 % respectively (see Figure 48A). The germinated soredia had the highest proportion of survivor in the North noting for 4.6%, while those on the South, West and East were 0, 1 and 2 % respectively (see Figure 48B). This study found that large numbers of the germinating diaspores from transplantation could not continue growing in natural habitat due to threaten by others flora and fauna. However, this

experiment demonstrated that the East aspect of the trunk was the most successful one for isidia transplantation, whereas the North was the best for soredia.



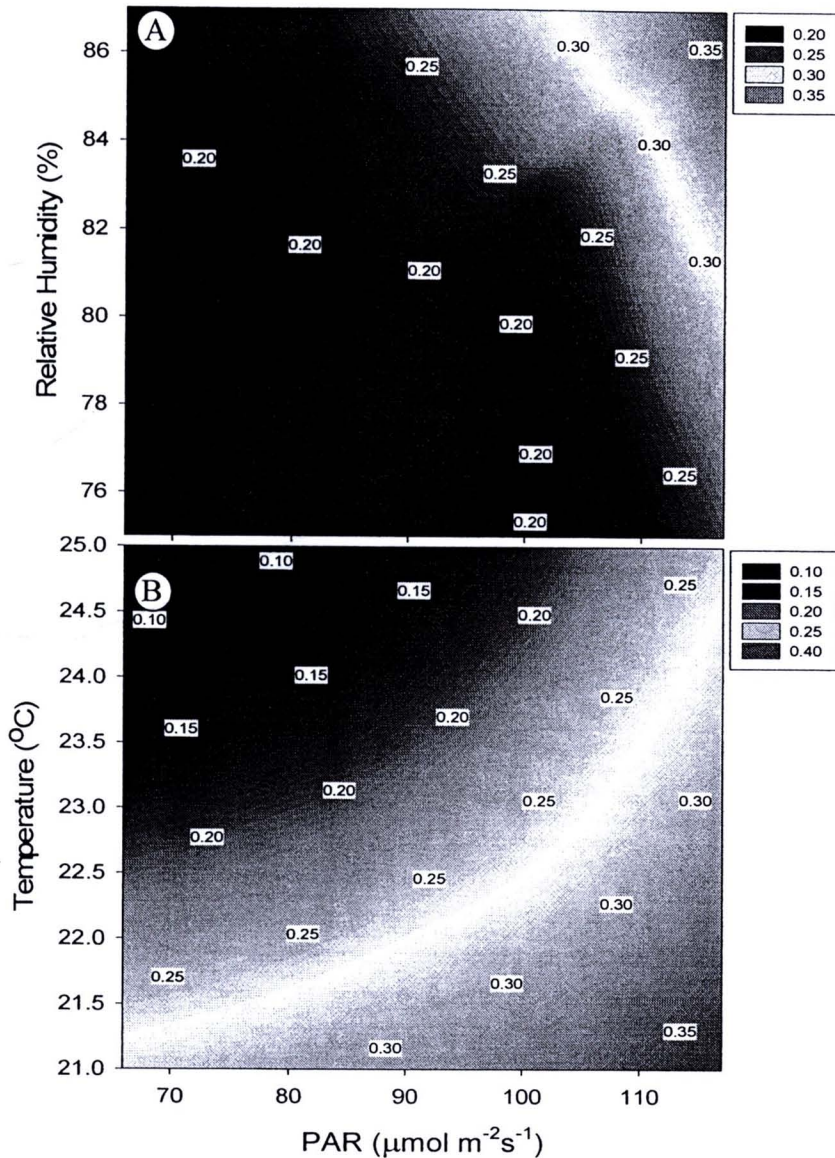
**Figure 48** Survival of germinated diaspores transplanted on four aspects of tree trunks.

*Note.* From researcher; survival of isidia (A) and soredia (B) on the North, East, South and West aspects during 62 months of transplantation during April 2004 to December 2008.

## ***Relationship Between Growth of Vegetative Propagules and Microclimate***

### ***Influence of Microclimate on Growth of Thallus Fragments***

Microclimate had considerable influences on growth rate of thallus fragments of *P. tinctorum* as showed by filled contour plots in Figure 49. Figure 49A showed that the increasing light intensity and relative humidity during photosynthetically active times (6:00 to 10:00 h) enhanced growth of the thallus fragments transplanted to LMF. The highest growth rate was achieved at relative humidity 82 to 90% and illumination exceeded  $100 \mu\text{mol m}^{-2} \text{s}^{-1}$ . Figure 49B demonstrated that decreasing temperature from 25 to 21 °C together with increasing light intensity from 70 to beyond  $100 \mu\text{mol m}^{-2} \text{s}^{-1}$ , enhanced growth rates. By contrast, the high temperature and the low humidity under the low illumination retarded growth rate.



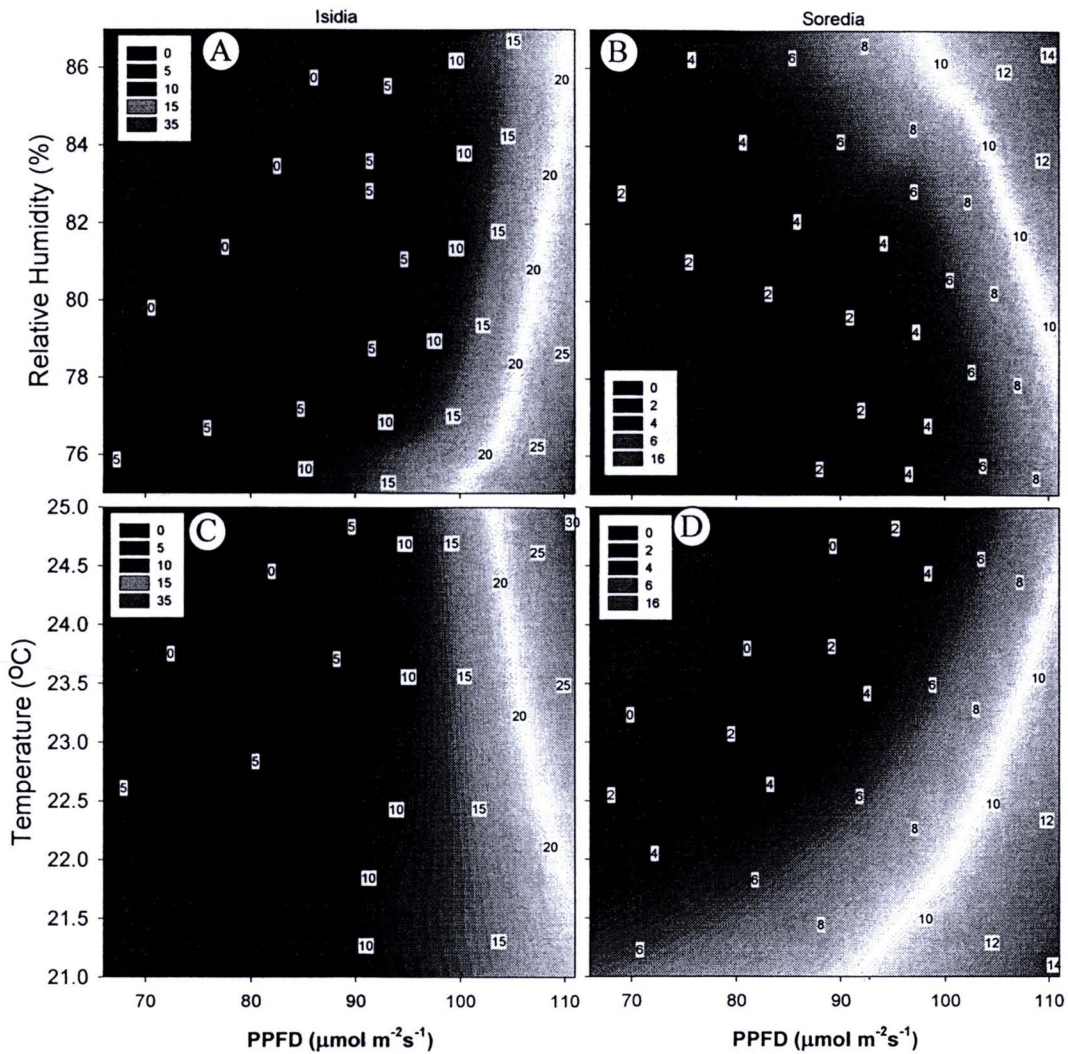
**Figure 49** Filled Contour Plots showed relationship between growth rate of thallus fragment with illumination, relative humidity and temperature after transplantation.

*Note.* From researcher; growth rates of thallus fragments of *P. tinctorum* were influenced by illumination (PAR) and temperature (A) PAR and relative humidity (B) after transplanted to TRF, DEF, SF and LMF. Microclimatic factors were measurements during photosynthetic active period of lichen during 6.00-10.00 h. Colors with numbers in clear boxes represented growth rate in mm/month.

### ***Influences of Microclimate on Diaspores Germination***

Germination of isidia and soredia were obviously influenced by light intensity, relative humidity and temperature. Germination of isidia increased with increasing illumination, humidity and temperature (see Figure 50A, C). Their germination could not be found at illumination lower than  $70\mu\text{mol m}^{-2} \text{s}^{-1}$ , RH below 80%. However, temperature exerted slightly different influence. Increasing temperature up to  $25^{\circ}\text{C}$  in high illuminated condition enhanced germination of isidia (Figure 50C). By contrast, germination of soredia increased with all three climatic factors. However, they were likely to have few germinations at low illumination. In addition low temperature of  $22.5^{\circ}\text{C}$  under high illumination enhanced soredia germination (see Figure 50D).

Obviously, isidia and soredia could not germinate at illumination lower than  $70\mu\text{mol m}^{-2} \text{s}^{-1}$ .



**Figure 50** Filled Contour Plots showed relationship between germination of isidia and soredia with illumination, relative humidity and temperature after transplantation.

*Note.* From researcher; germinations of isidia and soredia were influenced by illumination (PPFD) and relative humidity (A and B) and by PPFD and temperature (C and D) after transplanted to TRF, DEF, SF and LMF. Isidia was from *P. tinctorum* and soredia was from *P. presorediosum* Microclimatic factors were measurements during photosynthetic active period of lichen during 6.00-10.00 h. Colors with numbers in clear boxes represented growth rate in mm/month.

## **Survival and growth of Lichen Vegetative Propagules Transplanted on Artificial Substrates**

### ***Transplantation of Vegetative Propagules of Lichens on Artificial Substrates in Different Forests***

Ceramic tiles, rubber tile, wooden plate, galvanized iron, concrete block and brown glass-bottle were used as artificial substrates for transplantation of thallus fragments, isidia and soredia in LMF, TRF, DEF and SF. Effects of substrates in different forests on survival and growth of vegetative propagules of lichens were observed.

***Survival and growth of thallus fragments.*** Five months after transplantation (April 2006), thallus fragments transplanted on every substrate at DEF died completely. The substrates were grown over by vascular epiphytes. None of those transplantation on wooden at SF could survive, and large numbers of thallus fragments in the remaining forests barely survived on the artificial substrates used Table 12 and Figure 51A. The highest numbers of thallus survivors (24 thalli) were found on wooden plate and ceramic tile at LMF and SF. LMF had the highest proportion of survivors on all substrates accounted for 15%, and subsequently lower in SF and TRF noted for 14 and 13.4% respectively. Thallus fragments on galvanized iron and some ceramic tiles turned brown (see Figure 52 and Table 12). The remaining thalli continued to die after long period of transplantation.

At the end of observation period, 53 months after transplantation (May 2010), the largest number of survived thalli were found on glass bottles

accounting for 6, 5 and 1 thalli in TRF SF and LMF respectively (see Figure 53B). Two thalli survived on wooden board at LMF. Measured growth rates of these survived thalli in TRF and SF were 7.9 and 4.5 mm/yr respectively (see Figure 53).

After six months of transplantation (April 2006) neither isidia nor soredia germinated on any substrate in any forest (see Table 13). However, after ten months of transplantation (September 2006) numerous tiny lobes germinated from isidia and soredia over DSGT that attached on all substrates in every transplanted sites (see Figure 54A, Table 13, 14 and Figure 51B and C). Isidia had the highest proportion of germination from LMF, SF and TRF averaged 16%, 9% and 8.1 % respectively, whereas those of the soredia averaged 12%, 7% and 6.5% from the same forests. The highest numbers of germination were observed on glass bottles at LMF accounting for 17 and 18 samples from isidia and soredia respectively (see Table 13 and 14).

After transplantation for 25, 40 and 53 months (December 2007, April 2009 May 2010), the juvenile lobes developed from isidia and soredia declined during the courses of observation. Table 14 and 15 demonstrated that proportions of germination and development of juvenile lobes of isidia and soredia declined substantially. At the end of observation period, 53 months after transplantation, new thalli that developed from isidia and soredia existed only on glass bottles in all three transplanted forests except SF where soredia could not grow. The other substrates in the three transplanted sites completely failed to support development of juvenile lobes in long term period.

Nevertheless, numbers of survived thalli developed from isidia over glass

bottle varied, with the highest proportion of survival observed in TRF and subsequently lower in SF and LMF accounted for 3.9%, 2.3% and 1.2% respectively (see Table 13). Those developed from the soredia were 3.7% in TRF and 0.9% in SF (see Table 14). It is important to note that habitat encroachment by algae *Trentepohlia sp.* in LMF caused failure of development of the juvenile lobes germinated from isidia and soredia (see Figure 54B and C).

At the final observation period, juvenile thalli developed from soredia and isidia on glass bottles had diameters up to 3 and 2 cm respectively (see Figure 55). Growth rates of juvenile lobes from isidia and soredia were 2.25 mm/yr and 1.62 mm/yr respectively. This result revealed that substrate with smooth-glossy and curve surface, such as of glass bottle, was advantage over the others for successful germination and survival of isidia and soredia after transplantation. However, anchoring substrate, DSGT, for isidia and soredia must be provided.

Table 12

*Numbers of Thallus Fragments Survived After Transplanted on Various Substrates in Three Ecosystems During November 2005 to May 2010*

Substrates	No. of transplanted thalli	Number of thallus survival																	
		Lower montane rain forest (LMF)						Tropical rain forest (TRF)						Secondary forest (SF)					
		Apr- 06	Sep- 06	Dec- 07	Apr- 09	May- 10	Apr- 06	Sep- 06	Dec- 07	Apr- 09	May- 10	Apr- 06	Sep- 06	Dec- 07	Apr- 09	May- 10			
Wooden board	72	24	8	5	2	2	15	6	0	0	0	0	0	0	0	0	0	0	0
Ceramic tile	72	5	2	0	0	0	19	5	0	0	0	0	0	24	10	3	3	0	0
Concrete block	72	8	4	0	0	0	7	3	0	0	0	0	0	20	13	11	2	0	0
Glass bottle	72	13	6	6	3	1	10	10	8	6	6	6	8	8	8	5	5	5	5
Rubber tile	72	8	5	2	0	0	7	3	0	0	0	0	5	4	6	0	0	0	0
Galvanized iron	72	7	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
<b>TOTAL</b>	<b>432</b>	<b>65</b>	<b>25</b>	<b>13</b>	<b>5</b>	<b>3</b>	<b>58</b>	<b>27</b>	<b>8</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>60</b>	<b>35</b>	<b>25</b>	<b>10</b>	<b>5</b>	<b>5</b>	<b>5</b>
% survival	100	15.0	5.8	3.0	1.2	0.7	13.4	6.3	1.9	1.4	1.4	1.4	13.9	8.1	5.8	2.3	1.2	1.2	1.2

**Table 13**

*Number of Samples Holding Isidia Germinated After Transplanted on Various Substrates in Three Ecosystems During November 2005 to May 2010*

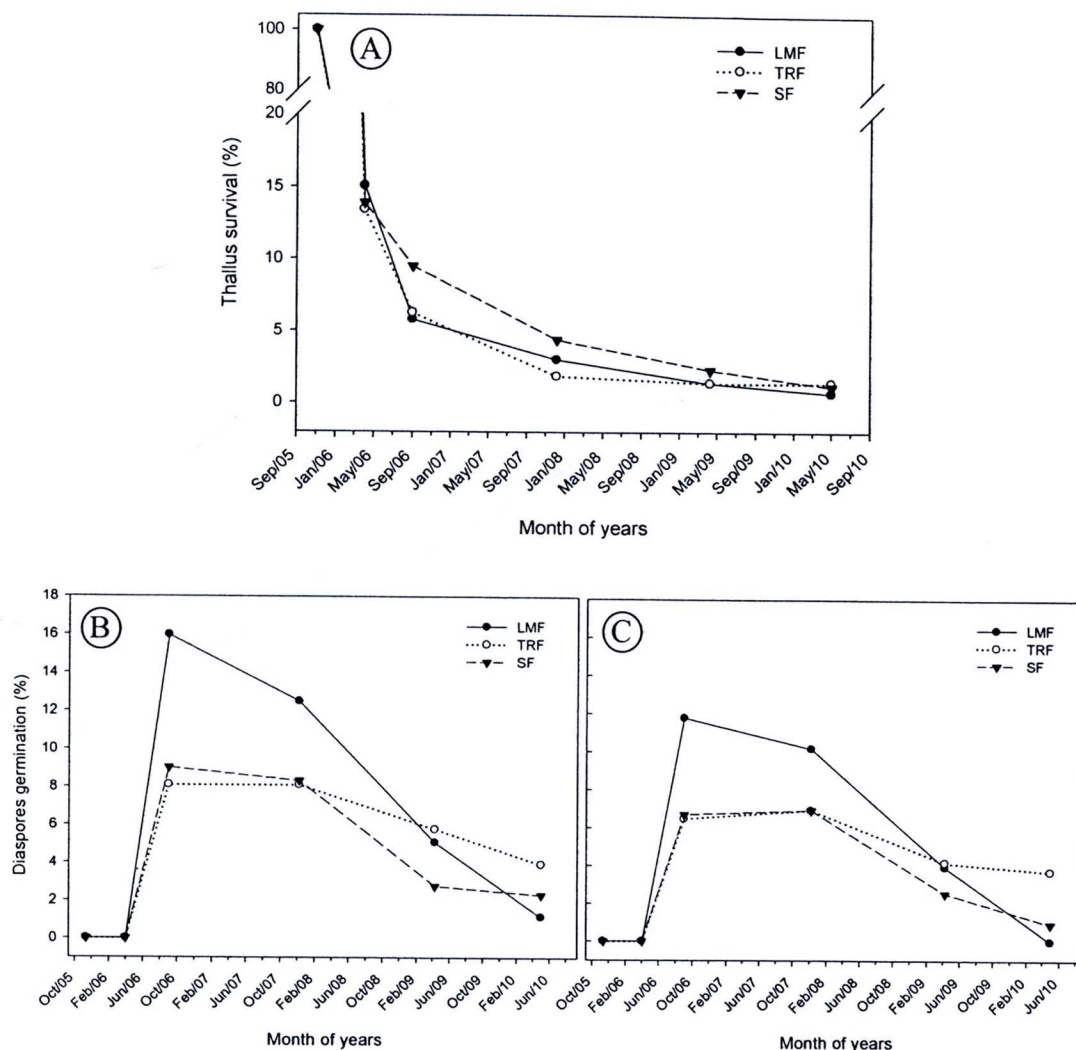
Substrates	No. of isidia samples transplanted	Number of survived samples																	
		Lower montane rain forest (LMF)						Tropical rain forest (TRF)						Secondary forest (SF)					
		Apr-06	Sep-06	Dec-07	Apr-09	May-10	Apr-06	Sep-06	Dec-07	Apr-09	May-10	Apr-06	Sep-06	Dec-07	Apr-09	May-10			
Wooden board	72	0	14	10	3	0	0	0	8	5	0	0	0	0	6	7	0	0	
Ceramic tile	72	0	16	12	5	0	0	7	7	6	4	0	0	10	9	0	0	0	
Concrete block	72	0	6	2	0	0	0	3	4	4	2	0	0	2	3	0	0	0	
Glass bottle	72	0	17	18	14	5	0	12	16	19	17	0	13	14	12	10	10	10	
Rubber tile	72	0	12	10	0	0	0	3	4	0	0	0	7	3	0	0	0	0	
Galvanized iron	72	0	4	2	0	0	0	2	0	0	0	0	1	0	0	0	0	0	
<b>TOTAL</b>	<b>432</b>	<b>0</b>	<b>69</b>	<b>54</b>	<b>22</b>	<b>5</b>	<b>0</b>	<b>35</b>	<b>35</b>	<b>25</b>	<b>17</b>	<b>0</b>	<b>39</b>	<b>36</b>	<b>12</b>	<b>10</b>	<b>10</b>	<b>10</b>	
% survival	100	0.0	16.0	12.5	5.1	1.2	0.0	8.1	8.1	5.8	3.9	0.0	9.0	8.3	2.8	2.3	2.8	2.3	



Table 14

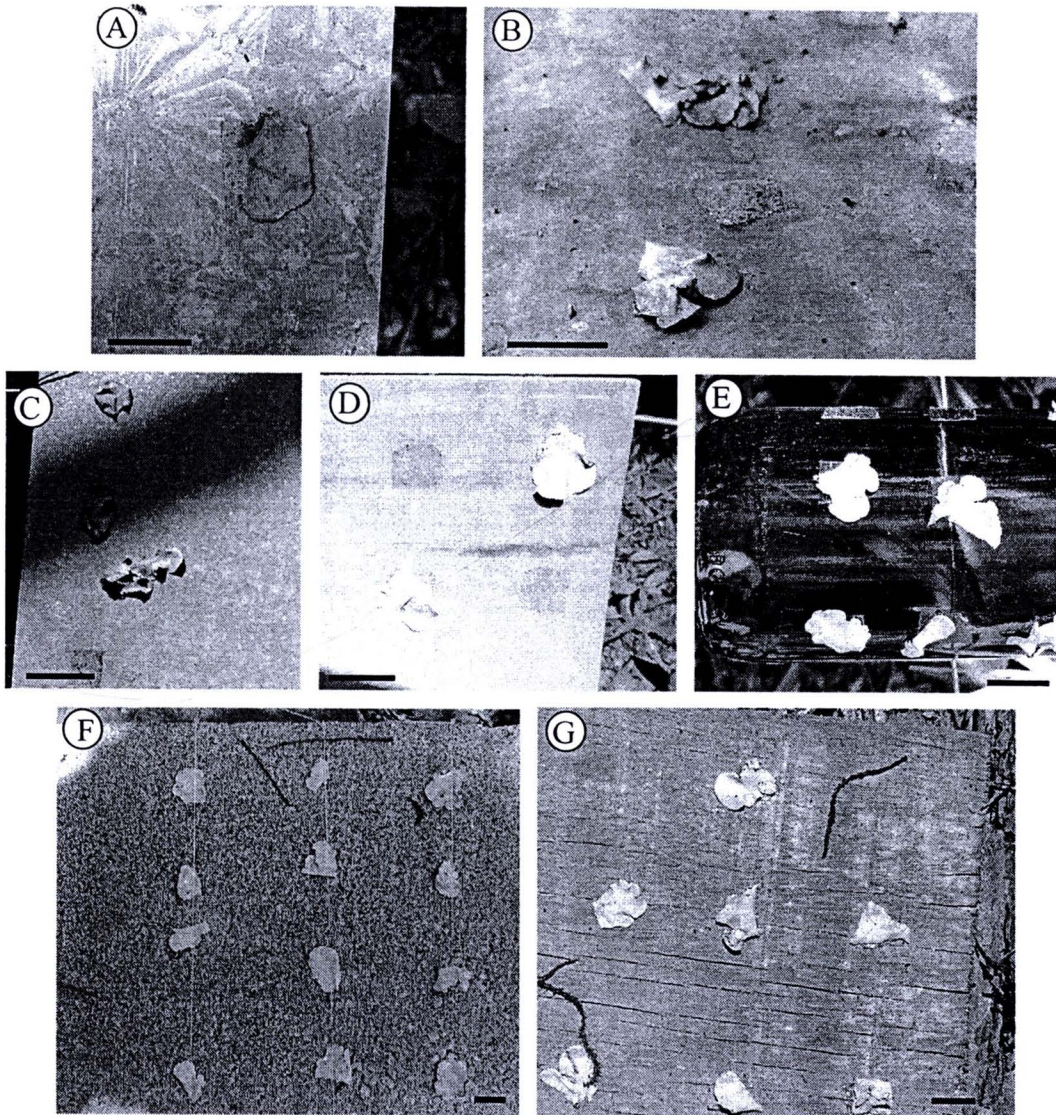
*Number of Samples Holding Soredia Germinated After Transplanted on Various Substrates in Three Ecosystems During November 2005 to May 2010*

Substrates	No. of soredia samples transplanted	Number of survived samples																				
		Lower montane rain forest (LMF)				Tropical rain forest (TRF)				Secondary forest (SF)												
		Apr-06	Sep-06	Dec-07	Apr-09	Apr-06	Sep-06	Dec-07	Apr-09	Apr-06	Sep-06	Dec-07	Apr-09	May-10								
Wooden board	72	0	8	8	3	0	0	0	0	0	3	5	0	0	0	0	4	4	7	3	0	
Ceramic tile	72	0	11	7	2	0	0	0	0	0	4	5	0	0	0	0	0	6	5	0	0	0
Concrete block	72	0	4	2	0	0	0	0	0	0	3	2	0	0	0	0	0	5	4	0	0	0
Glass bottle	72	0	18	19	12	0	0	0	0	0	16	18	18	16	0	0	0	11	12	8	4	4
Rubber tile	72	0	10	8	0	0	0	0	0	0	2	0	0	0	0	0	0	1	2	0	0	0
Galvanized iron	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
<b>TOTAL</b>	<b>432</b>	<b>0</b>	<b>51</b>	<b>44</b>	<b>17</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>28</b>	<b>30</b>	<b>18</b>	<b>16</b>	<b>0</b>	<b>0</b>	<b>29</b>	<b>30</b>	<b>11</b>	<b>4</b>	<b>4</b>	<b>4</b>
% survival	100	0.0	11.8	10.2	3.9	0.0	0.0	0.0	0.0	0.0	6.5	6.9	4.2	3.7	0.0	0.0	6.7	6.9	2.5	0.9	0.9	0.9



**Figure 51** Proportion of vegetative propagules survived after transplantation to various substrates.

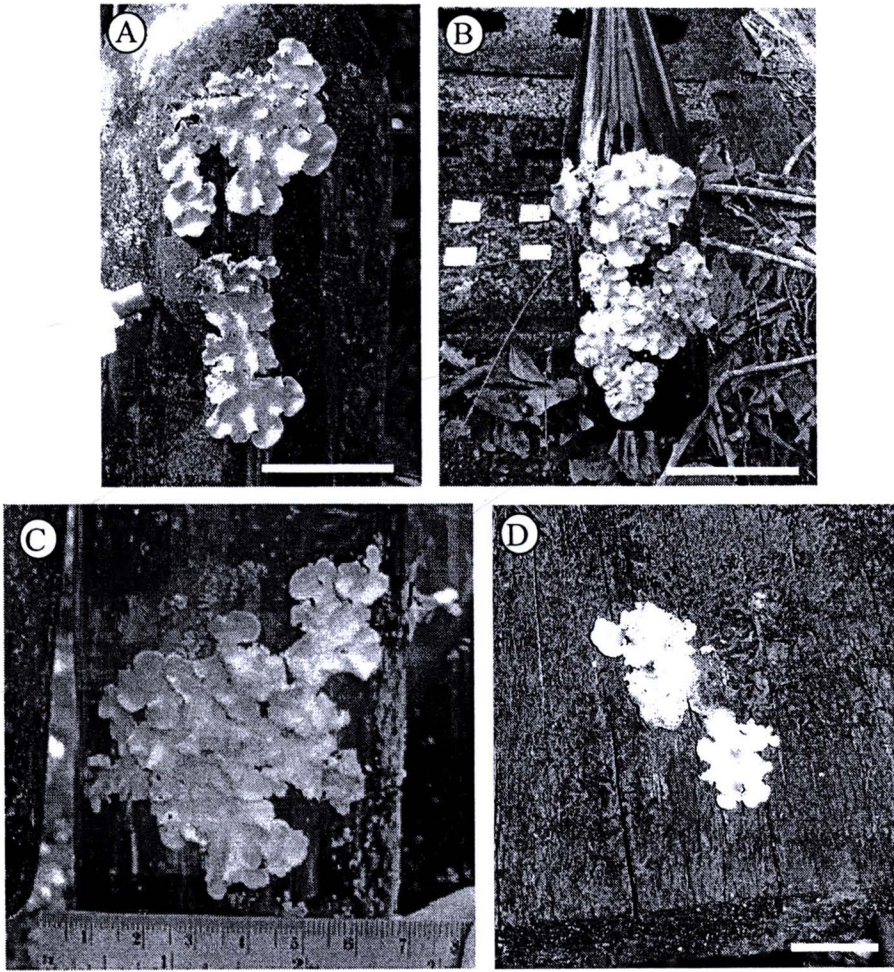
*Note.* From researcher; Total survivors after transplantation of thallus fragments (A), isidia (B) and soredia (C). These vegetative propagules were transplanted on ceramic tiles, rubber tile, wooden board, galvanized iron, concrete block and brown glass-bottle in Tropical rain forest (TRF), Lower montane forest (LMF) and Secondary forest (SF).



**Figure 52** Thallus fragments after 25 months of transplantation on various substrates.

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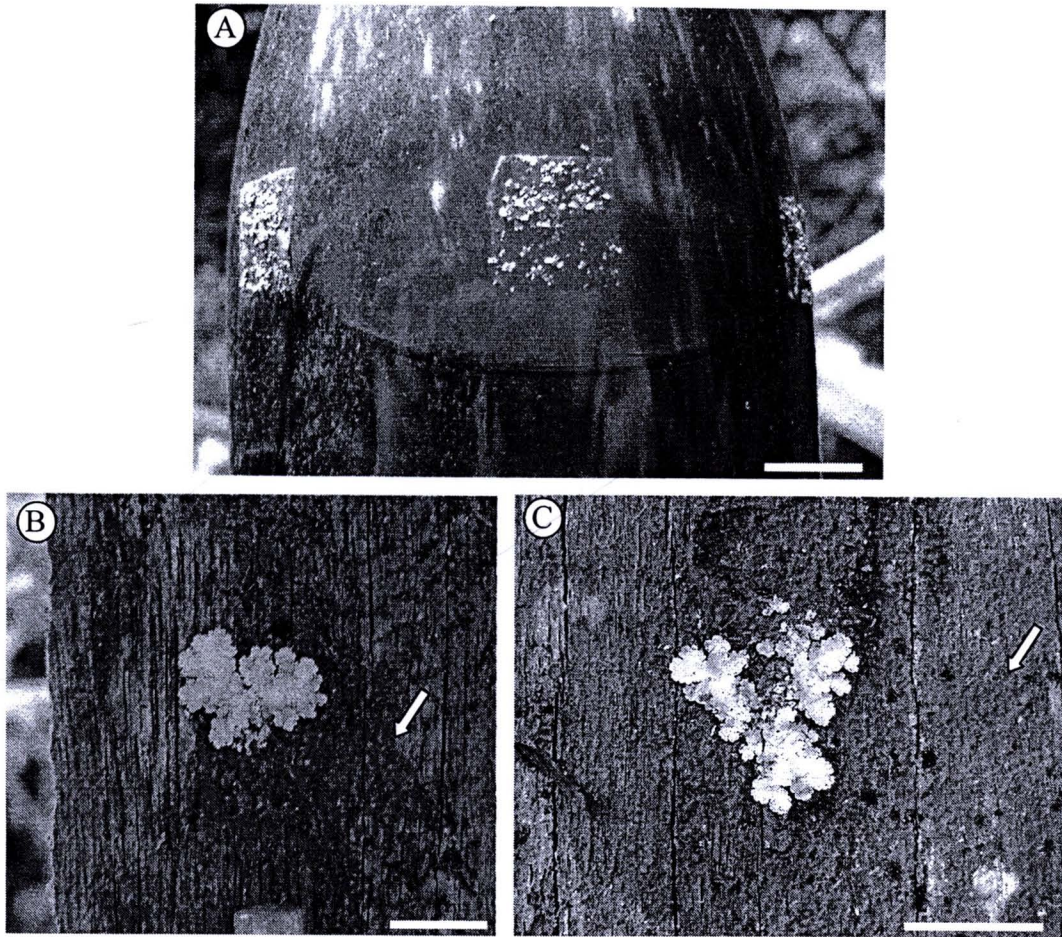
*Note.* From researcher; thallus fragments of *P. tinctorum* on galvanized iron at the beginning and after transplantation (A and B). Thallus survival on Ceramic tile (C), Rubber tile (D), Glass bottle (E), Concrete block (F) and Wooden board (G). (scale bars = 1cm.)



**Figure 53** Thallus fragments grew on glass bottle and wooden board after transplantation.

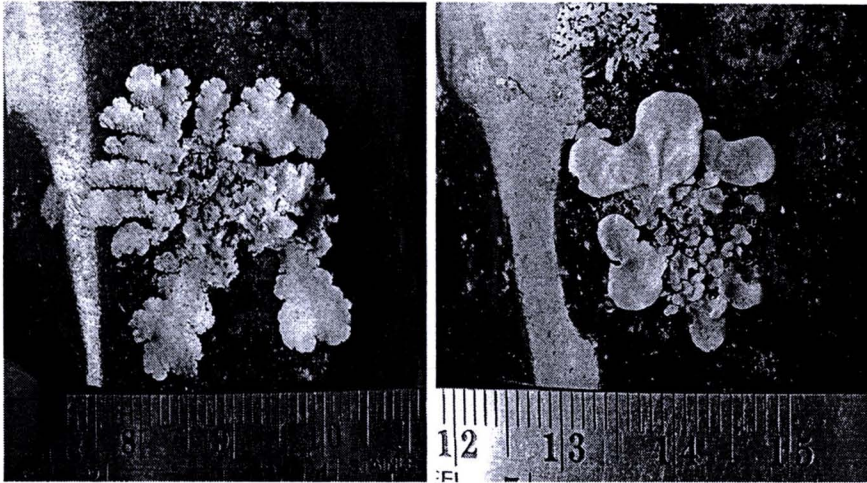
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*Note.* From researcher; thallus grew on glass bottle after 25 months of transplantation at LMF (November 2005 to December 2007) (A), and 53 months after transplantation in TRF (B) and SF (C) (November 2005 to May 2010). (scale bar; A = 3 cm, B = 5cm and D = 1cm.)



**Figure 54** Diaspores germination on glass bottles and wooden board in LMF.

*Note.* From researcher; germination of diaspores after 10 months of transplantation (November 2005 to December 2007) (A). Juvenile lobes of about 1 cm diameter on wooden board in LMF (B, C) and the arrows indicated the threaten algae *Trentepohlia* sp. which only occurred in LMF (November 2005 to April 2009). (scale bar = 1cm)



**Figure 55** Juvenile thalli germinated from diaspores on glass bottle at tropical rain forest after 53 months of transplantation.

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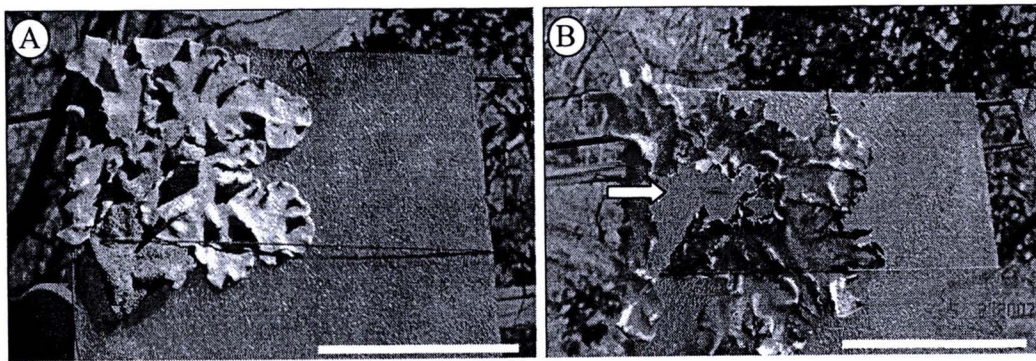
*Note.* From researcher; completed thallus developed from soredia of *P. sancti-angelii* (A) and isidia of *P. tinctorum* (B). Transplantation period was November 2005 to May 2010.

### ***Transplantation of Thallus Fragments on Polycarbonate Plates Under Canopy of SF***

Establishment and growth of thallus fragments of *P. tinctorum* were observed after transplanted on polycarbonate plates under the canopy of SF during June 2004 to August 2007 (see Figure 56). Numbers of survived thalli declined substantially after transplantation (see Figure 57A). Sixty seven percent of the transplanted thallus fragments survived after six months of transplantation. However, after 17 and 24 months of transplantation only 52% and 32% of the thalli remained on the substrates. At the end of

observation period, 39 month after transplantation, only 9% of thalli survived (see Figure 57A).

Average growth rate of the survived thalli was 0.62 mm/month during the whole period of observation. Maximum average growth rate of 0.93 mm/month was observed in June 2006 during the rainy season (see Figure 57B). An individual thallus achieved the maximum growth rate as much as 1.58 mm/month was observed (see Table 15). One thallus had area increased up to eight times of its original.

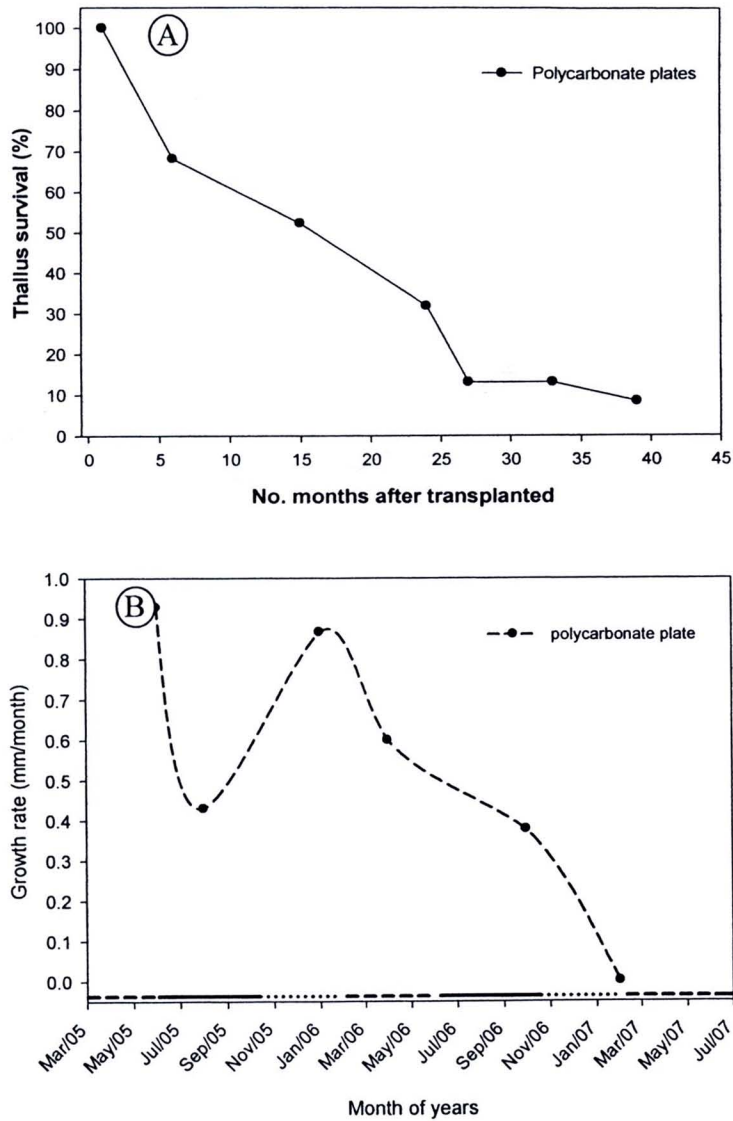


**Figure 56** *P. tinctorum* grew on polycarbonate plate in SF after 22 months of transplantation by using thallus fragment.

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*Note.* From researcher; completed thallus (A) degenerated thallus (B).

Transplantation was performed under canopy of SF. (scale bars = 5cm.)



**Figure 57** Survival of thallus fragments and growth after transplanted on polycarbonate plates in SF.

*Note.* From researcher; thallus fragments of *P. tinctorum* survived (A) and grew (B). (— wet season, ..... cold season and - - - hot season)

**Table 15**

*Growth Rates of Thallus Fragments of P. tinctorum After Transplanted on Polycarbonate Plates Installed Under Canopy of SF During 35 Months of Observation*

Observation (month/year)	No. of Thallus (n)	Thallus growth			
		Thallus sizes		Growth rates (mm/month)	
		Area (cm <sup>2</sup> )	Diameter (cm)	Average	Maximum
Feb-04	9	3.97	2.31	-	-
Jun-05	3	13.82	4.12	0.93	1.52
Aug-05	2	7.84	3.19	0.43	0.64
Jan-06	8	14.90	4.27	0.87	1.23
Apr-06	9	15.47	4.37	0.60	1.58
Oct-06	2	29.71	6.22	0.39	0.76
Feb-07	2	28.74	6.02	0*	0*
Mean				0.62	0.96

*Note:* Thallus growths were measured from thalli that had expanded areas.

### ***Transplantation of Thallus Fragments on Plastic Nets and Ceramic Tiles Under Shading Net in SF***

Thallus fragments of *P. tinctorum* were transplanted on plastic nets and ceramic tiles. The transplanted materials were installed under green shading net under canopy of SF. Survival and growths were observed at time intervals during May 2005 to November 2008). Plastic net had better ventilation than ceramic tiles, which affect survival and growth of the transplanted lichens (see Figure 58).

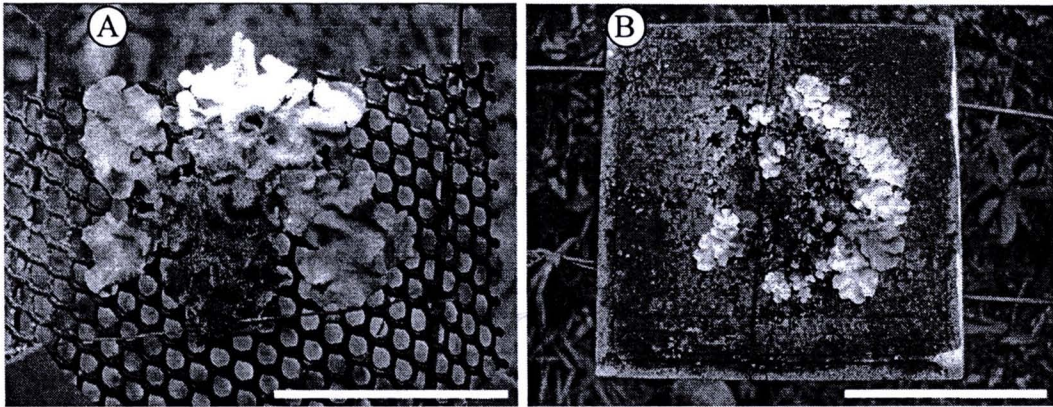
**Plastic nets.** Survived thalli declined sharply within 12 months of transplantation (see Figure 59A). Thereafter, between 12-23 months, lesser decline of the survivors was observed. During 28 to 43 months of transplantation numbers of the survived thalli seem to stable accounting for fifteen percent of the initial transplanted materials.

Average growth rate of the survived thalli was 0.44 mm/month, with the maximum of 0.56 mm/month occurred in October 2006 after the rainy season. The minimum growth of 0.27 mm/month was observed in April 2007 at the end of dry season. The maximum growth of an individual thallus as much as 1.47 mm/month was observed in November 2007 (see Table 16 and Figure 59B, 60 and 61).

**Ceramic tiles.** Seventy-eight percent of the thallus fragments died within 2 months after transplantation on ceramic tiles (see Figure 59A). Death of the transplanted thalli went on until the last observation. After 45 months of transplantation, only 5% of the transplanted thalli remained intact. Habitat encroachment by the algae *Scytonema* sp. was the main cause of death of the transplanted thalli (see Figure 62B and C). Water holding capacity of ceramic tile probably favored growth of this algae. It grew abundantly on this kind of substrate in 10 months after transplantation.

After the critical period of establishment during the first few months of transplantation, growth rates of were measured (see Table 17). Average growth rates of the survived thalli accounted for 0.79 mm/month, which was higher than those observed on plastic net. The highest averaged of growth rate of 0.95 mm/month was noted in June 2008. The maximum growth rate of 1.20

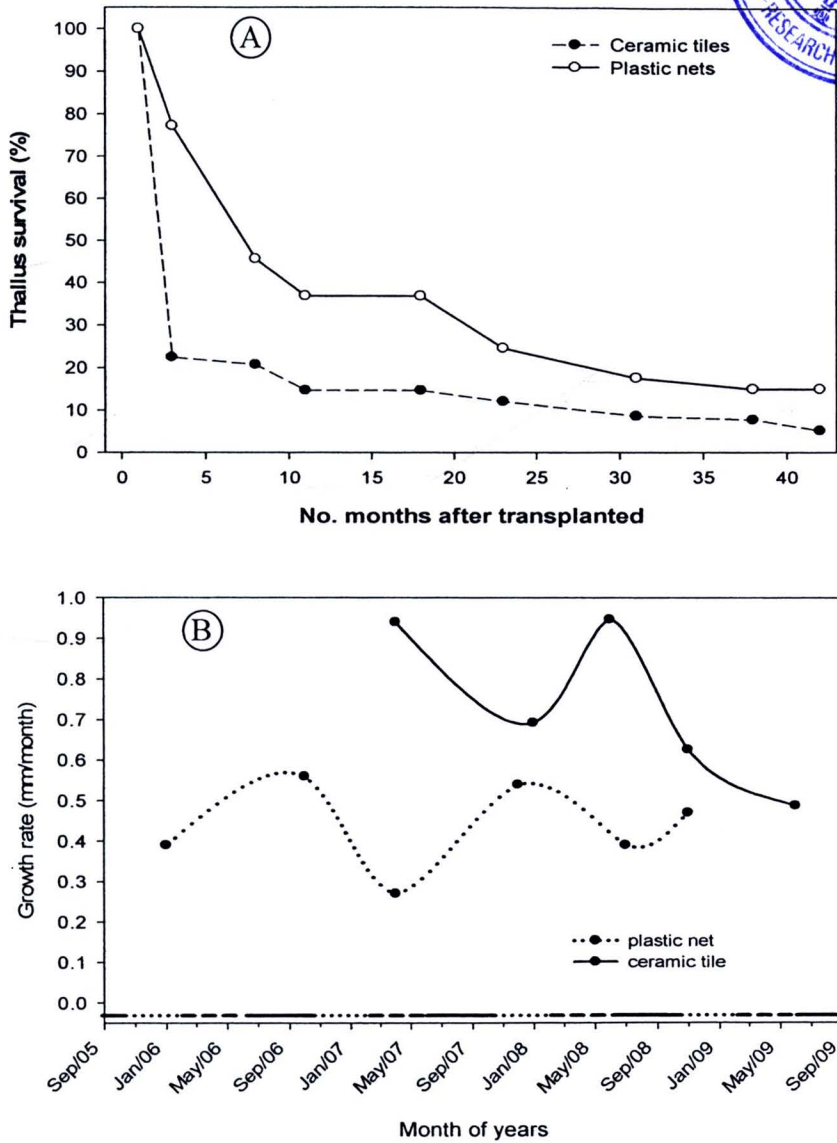
mm/month was recorded from an individual thallus measured after wet season (see Figure 59B).



**Figure 58** Thallus fragments of *P. tinctorum* grew on plastic net (A) and ceramic tiles (B) after 22 months after transplantation.

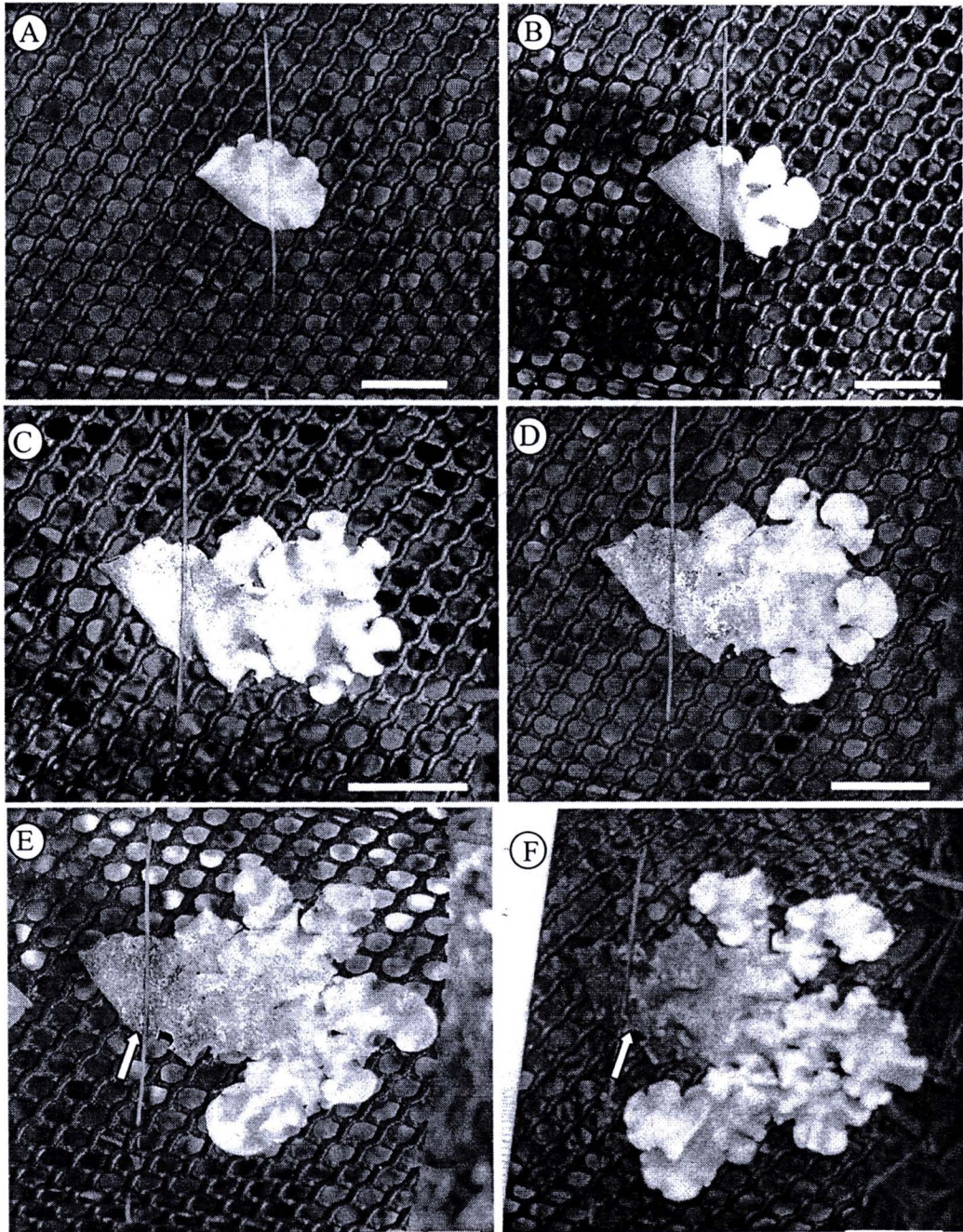
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*Note.* From researcher; scale bars are 5cm.



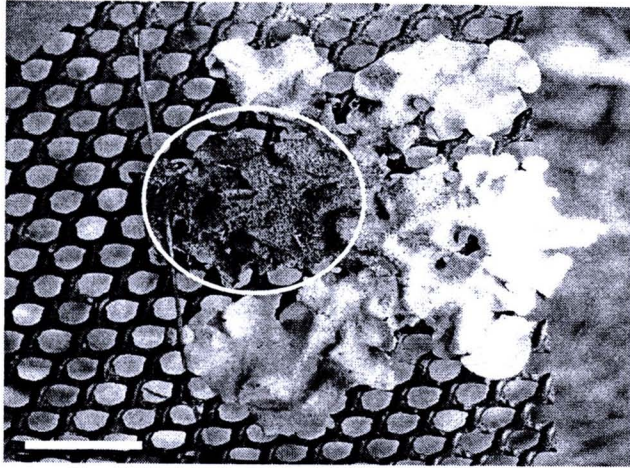
**Figure 59** Growth rate of thallus fragments of *P. tinctorum* after transplanted on plastic net and ceramic tiles in SF.

*Note.* From researcher; thallus survival (A) and growth rate (B) of thallus fragments transplanted on plastic net and ceramic tiles (— wet season, ..... cold season and - - - hot season)



**Figure 60** Expansion of thallus fragments of *P. tinctorum* after transplanted on plastic nets.

*Note.* From researcher; Transplanted thallus at initial stage (A), after transplantation for 6 months (B), 15 months (C), 21 months(D), 29 month (E) and 36 months (F). Arrows showed dark-brown death area of the original thallus fragment used in transplantation (E and F). (scale bars = 1cm.)



*Figure 61* New lobes grew from a thallus fragment of *P. tinctorum* after transplanted on plastic net for 43 months.

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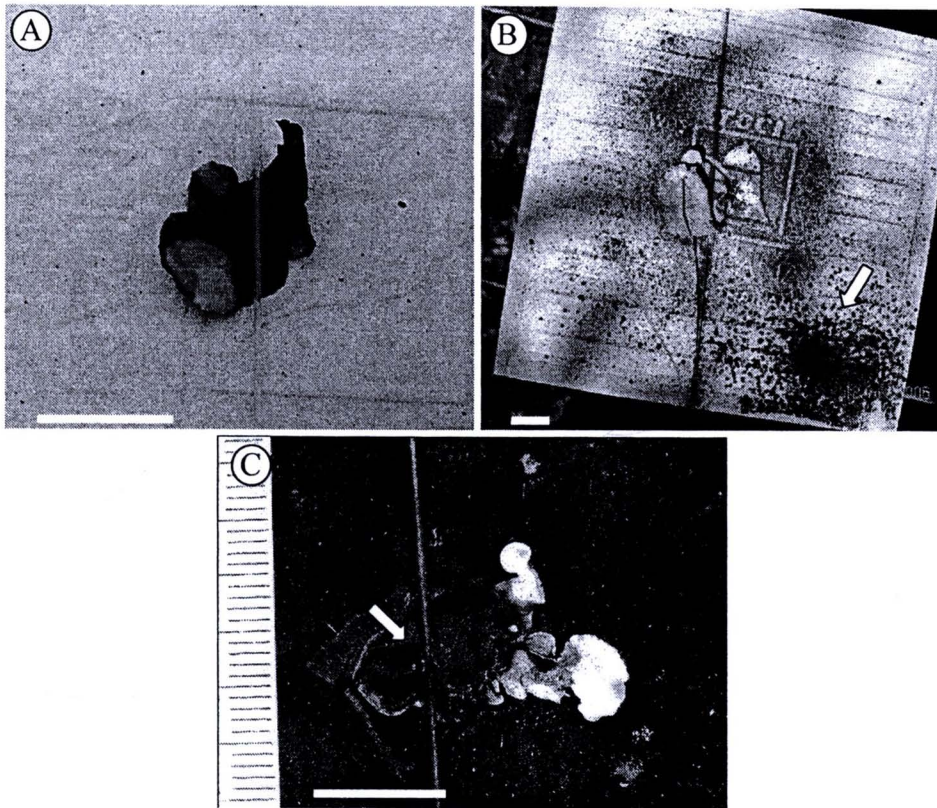
*Note.* From researcher; Transplantation was performed under green shading net installed under canopy in SF during October 2006 to November 2008.

White circle enclosed the original transplanted thallus which died later. (scale bars = 1cm.)

**Table 16**

*Sizes and Growth Rates of the Survived Thallus Fragments of P. tinctorum During 35 Months After Transplantation on Plastic Nets (n=27)*

Observation (month/year)	No. of Thallus (n)	Thallus growth			
		Thallus sizes		Growth rates (mm/month)	
		Area (cm <sup>2</sup> )	Diameter(cm)	Average	Maximum
Sep-05	27	2.32	1.73	-	-
Jan-06	27	2.83	1.90	0.39	0.8
Oct-06	27	4.52	2.39	0.56	0.94
Apr-07	27	5.15	2.54	0.27	1
Nov-07	19	6.77	2.90	0.54	1.43
Jul-08	17	6.57	2.75	0.39	1.47
Nov-08	17	5.18	2.35	0.47	0.91
Mean				0.44	1.09



**Figure 62** Thallus fragment of *P. tinctorum* died after transplanted on ceramic tile in SF.

*Note.* From researcher; death caused by substrate interaction after a few months of transplantation (A), and substrate encroachment by the algae *Scytonema* sp. occurred after 12 and 22 months of transplantation (B and C). Transplantation was performed under shading net installed under canopy of SF. Arrow pointed at algae *Scytonema* sp. (scale bars = 1 cm).

**Table 17**

*Sizes and Growth Rates of the Thallus Fragments of P. tinctorum Survived on Ceramic tiles During 35 Months of Transplantation (July 2005 to June 2009)*

Observation (month/year)	No. of Thallus (n)	Thallus growth			
		Thallus sizes		Growth rates (mm/month)	
		Area (cm <sup>2</sup> )	Diameter (cm)	Average	Maximum
Dec-06	2	3.20	2.03	-	-
Apr-07	4	6.07	2.78	0.94	0.98
Jan-08	6	8.24	3.22	0.69	0.93
Jun-08	7	9.86	3.44	0.95	1.20
Nov-08	7	12.18	3.82	0.63	1.15
Jun-09	2	16.41	4.50	0.49	1.05
Mean				0.79	1.06

*Note.* Thallus growths were calculated from those that show increasing areas at each observation period.

***Transplantation of Isidia on Nylon Net at Different Angles of Inclination Under Shading Net in SF***

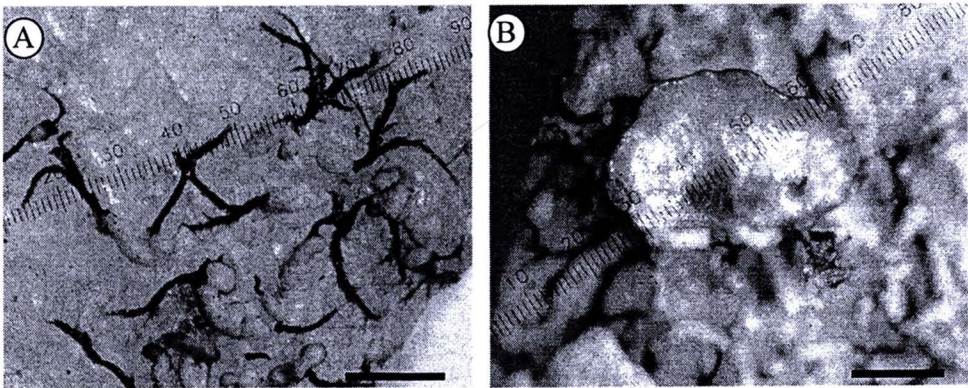
Different angles of inclination of substrates receive varying light intensity over the surfaces, which affected period of drying of substrates. The influences of this condition on establishment, survival and growth on lichen transplantation were investigated by transplantation isidia of *P. sulfuratum* by spreading over DSGT and attached on nylon net. The transplanted materials were installed on horizontal, vertical levels and 45° inclination under shading net in SF. Installation of samples was described in materials and methods (p. 56-57). Transplantation period lasted from June 2007 to December 2008.

***Germination and survival of isidia of P. sulfuratum on inclined substrates.*** Germination of isidia into recognizable juvenile lobes with long black rhizines was obvious after 4 months of transplantation (June to October 2006) (see Figure 63A). Germination as much as 90% and 50% of isidia samples occurred on 45° and 90° slopes respectively.

Six months after transplantation, some juvenile lobes had 1 mm diameter, and continued to grow rapidly on 45° slopes (see Figure 64). Cross section of the biggest juvenile lobes showed typical anatomy of foliose thallus. It had stratified of heteromorous thallus including thin upper cortex, algae layer, medullar and dense tissue of lower cortex (see Figure 64B).

During 6 to 24 months after transplantation, 70% and 30% of germinated isidia samples existed on 45° and 90° respectively, whereas samples on the horizontal substrates failed to germinate. Thirty-two months after transplanted, 50% of the germinated isidia remained intact on 45°

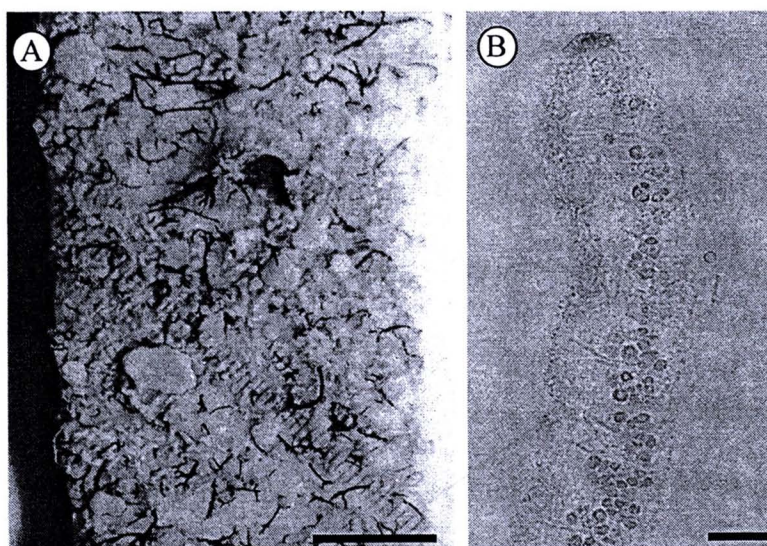
inclined substrates, with one sample had the thallus covered the entire DSGT. This thallus later expanded beyond the substrate as showed in Figure 65. On the contrary, all of the samples transplanted to the vertical and horizontal substrates had no evidence of growth.



**Figure 63** Germination of isidia of *P. sulphuratum* on 45° inclined nylon net in SF.

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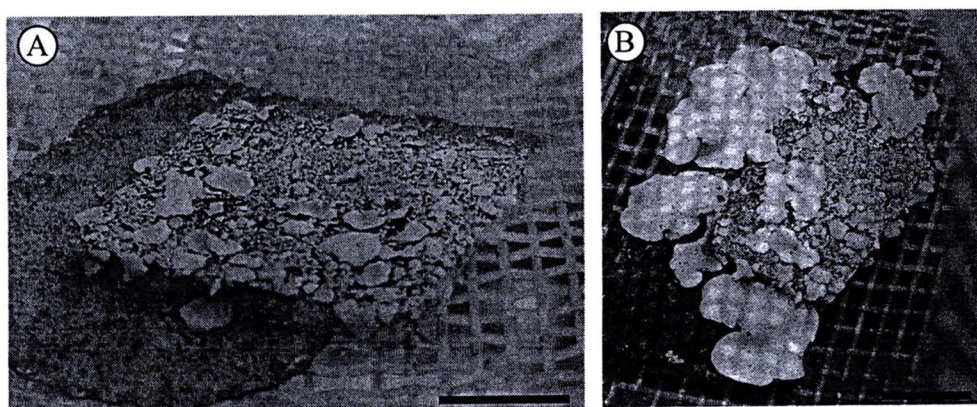
*Note.* From researcher; Long black rhizines protruded from juvenile lobes developed from isidia of *P. sulphuratum* (A) and lower surface of new lobe developed from isidia of *P. sulphuratum* (B) after 4 months of transplanted. The isidia were spread on DSGT and fixed on 45° inclined nylon net installed under shading net under canopy of SF (June to October 2006). (scale bar = 1µm)



**Figure 64** Juvenile lobes developed from isidia of *P. sulphuratum* after four months of transplantation to SF.

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*Note.* From researcher; Juvenile lobes with black rhizines developed from isidia (A) x-section of thallus show heteromorous stratification of photobiont and mycobiont (B) after transplantation during June to October 2006. (Scale bar; A = 1mm and B =10  $\mu$ m)



**Figure 65** Juvenile thalli of *P. sulphuratum* germinated from isidia densely covered DSGT after 19 and 32 months of transplanted in SF.

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*Note.* From researcher; Juvenile thalli of *P. sulphuratum* grew almost completely covered DSGT after 19 months (June 2006 to December 2007) (A) and 32 months of transplantation (June 2006 to December 2008) (B). (scale bar = 5 mm)

***Germination and Growth of Isidia and Soredia on 45° Inclined Nylon Net Under Shading Net in SF***

***Development of isidia and soredia.*** Fifty samples of each isidia from *P. tinctorum* and soredia of *P. sancti-angelii* were transplanted on 45° inclined nylon nets installed under shading net in SF. It was found that the first juvenile lobe germinated from these diaspores after transplanted for 4 months (see Figure 66A and C), however they could not be recognized their taxa. Ten months after transplanted, soredia grew rapidly and developed long back cilia along lobe margin, which is character of *P. sancti-angelii* (see Figure 66C). Whereas, isidia of *P. tinctorum* grew slowly and some of them started to disintegrate (see Figure 66A and B). Twenty-two and 36 months after transplantation, juvenile thalli developed from soredia were larger than those from isidia (see Figure 66B, D and E).

***Proportion of isidia and soredia germination.*** After ten months of transplantation, proportion of soredia germination was 84.5% (see Table 18), which was about twice as much of those from the isidia (42.2%). After 23 months of transplantation, germination increased to 92% and 76% of soredia and isidia. Thereafter both germinating diaspores declined significantly. After 36 months the germinated isidia existed only 6%, while those of the soredia was only 2% during May 2007 to March 2010.

The maximum numbers the germinated isidia and soredia were observed in the 23<sup>rd</sup> months of transplantation (see Table 18). After this period status of the germinated diaspores were classified into six classes ranged from 0 to 5 according to thallus covers on DSGT (see Figure 67). It was found that

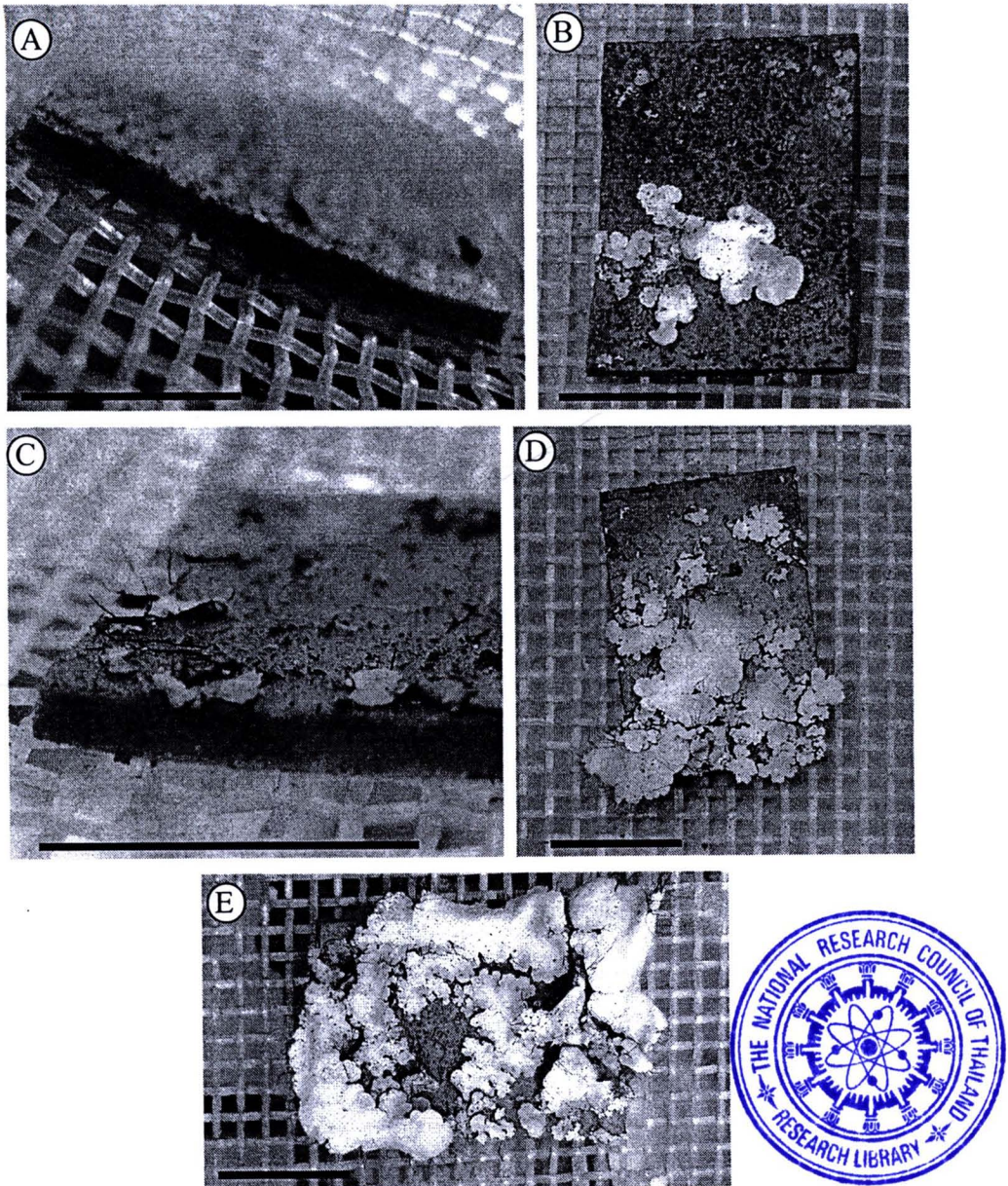
soredia had significant higher proportion of cover than isidia ( $P < 0.001$ ). Five soredia samples were classified as class 5 (see Figure 67F), while only one isidia sample had enough cover to be categorized in this class. Despite different taxa, however, this experiment indicated better capacity of soredia for establishment and regeneration in SF.

**Table 18**

*Numbers of Transplanted and Percent Germinations of Isidia from P. tinctorum and Soredia from P. sancti-angelii During 10, 23 and 36 Months of Transplantation on 45° Inclined Nylon Net Installed Under Shading Net in SF. Transplantation was Carried out on Four Plots*

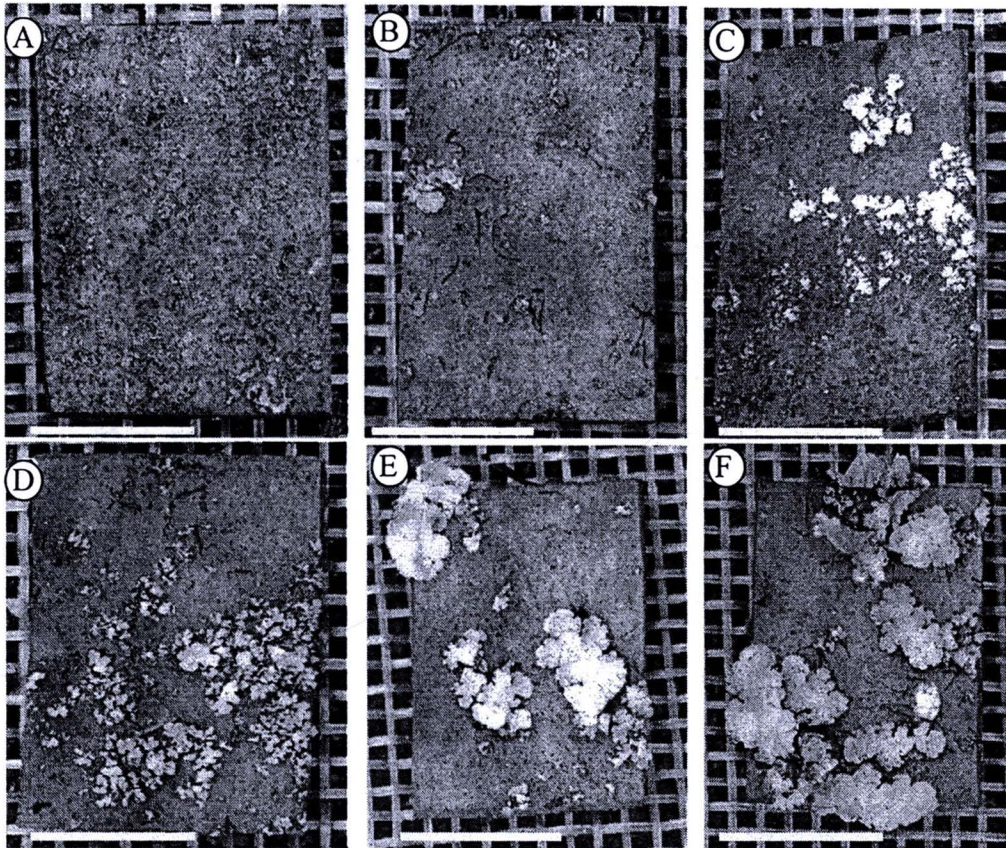
Plots Number	No. of transplanted isidia-soredia	Germination (%)					
		Isidia (I)			Soredia (S)		
		10 m	23 m	36 m	10 m	23 m	36 m
1	15-15	13.3	73.3	80.0	93.3	100	100
2	9-15	55.6	66.7	66.7	66.7	86.7	80.0
3	13-7	53.8	84.6	38.5	85.7	85.7	85.7
4	13-13	46.2	76.9	92.3	92.3	92.3	92.3
	Average	42.2	76.0	70.0	84.5	92.0	90.0

*Note.* m = months after transplantation



**Figure 66** Germination of isidia and soredia on DSGT after transplantation on 45° inclined substrate in SF.

*Note.* From researcher; Germination on DSGT after 10 months transplantation of isidia of *P. tinctorum* (A) and soredia of *P. sancti-angelii* (C) and 23 months after transplantation of isidia (B) and soredia (D) The largest thalli developed from soredia covered DSGT almost completely after 36 months of transplantation. The juvenile lobes had recognizable cilia that characterized *P. sancti-angelii* (E). (scale bar 5 mm).



**Figure 67** Classification of germinating soredia on DSGT into six classes after 23 months of transplantation.

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*Note.* From researcher; development of thalli germinated from isidia or soredia that covered DSGT; Class 0, no growth (A); class 1, 1-10% cover (B); class 2, 10-20% cover (C); class 3, 20-40% cover with small lobes (D) ; class 4, 20-40% cover with larger lobes (E); class 5, > 40% cover (F). The transplantation was performed on 45° inclined nylon net under shading net under canopy of SF. (scale bar = 5mm)