CHAPTER 5

THE DISTRIBUTION OF PINE CATERPILLAR OUTBREAK AND OTHER RELATIVE FACTORS

5.1 Pine caterpillar epidemic in Thua Thien Hue province

5.1.1 Pine caterpillar outbreak occurrence in study period

The pine caterpillar in Thua Thien Hue province was emigrated from another provinces of Northern part of Vietnam. Firstly, it was emigrated from South China to North Vietnam and spread down to the South of the country. During the immigration, the host of this pest changed with locations. The initial host of this pest was mason pine (*P. massoniana*) but when they came to the central and south of Vietnam, the host was not only mason pine but also merkus pine (*P. merkusii*) (DFD, 2001). In Thua Thien Hue province, the first outbreak of pine caterpillar occurred in 1987, although this kind of pest was recorded in the early of 1980s (Duc, 2000). From 1987 to 2003, it was recorded that the pine caterpillar outbreak occurred in 12 years (about 70.6%) during the 17-year period. It became more frequent from 1987 to 1996. During the next seven years, the frequency of the outbreak reduced, and the was no epidemic in year 1997, 1998, 2000, 2001, and 2002. However, in year 2003, it occurred again in small scale. Those are shown clearly in Table 5.1.

The area infected by pine caterpillar outbreak varied with years. The largest infected area was about 1,250 ha in 1989. After that, the infected area was reduce gradually and the smallest infected area was about 2.7 ha in 2003. For the 17-year period, more than 5,540 ha of pine forests were infected by pine caterpillar. There was no outbreak occurred in five years because the density of larvae in those years was not too high, so the damage was not serious. This is a normal situation in nature.

Table 5.1: Pine caterpillar outbreak and its damage.

Year	Area infected	Period occur		Age of forest	Prevention method	
		From	To		Manual	Chemical
	-----ha-----			----years----	----------ha----------	
1987	20.5	Nov-87	Jan-88	5 to 9	10.1	-
1988	700.0	Nov-88	Jan-89	6 to 10	405.0	-
1989	1,250.0	Nov-89	Feb-90	5 to 11	328.0	-
1990	693.5	Dec-90	Jan-91	9 to 11	600.0	93.5
1991	718.1	Dec-91	Jan-92	9 to 13	671.8	41.3
1992	363.0	Dec-92	Jan-93	9 to 13	363.0	-
1993	364.0	Nov-93	Jan-94	9 to 13	364.0	-
1994	568.7	Nov-94	Feb-95	10 to 16	520.1	46.1
1995	602.4	Nov-95	Jan-96	10 to 14	489.5	102.9
1996	212.9	Dec-96	Jan-97	9 to 13	200.0	-
1999	44.3	Dec-99	Jan-00	10 to 12	44.3	-
2003	2.7	Dec-03	Jan-04	12	2.7	-
Total	5,540.1	Nov. to Feb. next year		5 to 16	3,998.5	283.8

(Source: TTH DFP, 2004).

Some methods were developed and applied to control the outbreak of this pest. The manual method has been the most popular method. This method is very simple in which a stick is used to shake the branches of a tree so that the larvae dropped on the ground and being collected. This method was used to reduce the density of larvae under the threshold of the outbreak. This method has many advantages. First of all, it is a physical method so it does not affect the environment. Secondly, it makes use of unoccupied labors. Finally, the method can be used anywhere in any kind of the forests. By using this method, about 4,000 ha (accounting for 72.2%) of the forest was devoid of the pest. While the area controlled by other methods, such as chemical, was about 284 ha (5.1%) only. When the outbreak occurred in a large area with high density of larvae the biochemical and chemical pesticides were applied but their effectiveness was not usually high due to the complication of topography (Table 5.1).

In general, the age of forest commonly infected by the pine caterpillar ranged from five to 16 years old in Thua Thien Hue province. In other provinces in the North, however, the outbreak often happened to the forests aged between 7 and 21 years old (DFP, 2001). The time of the outbreak of the pest is also different between Thua Thien Hue Province and others. While in Thua Thien Hue, the suitable time for the outbreak was from November to February, in Northern provinces, it was from June to September (DFP, 2001). The differences may be caused by different climate conditions as well as different development stages of larvae (Duc, 2000; Dien, 1997).

5.1.2 The distribution of outbreak occurrence depending on age of forest

The relationship between pine caterpillar outbreaks and the age of forests is indicated clearly in the Figure 5.1 showing the frequency of pest outbreak occurrence at different ages of forests.

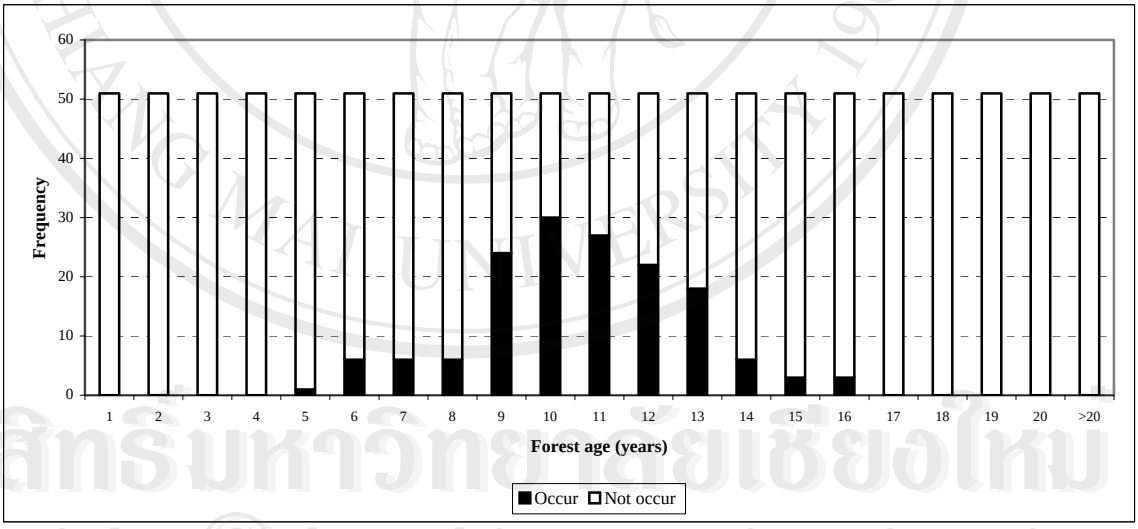

Figure 5.1: The epidemic occurrence of pine caterpillar in different forest ages. *(Source: TTH DFP, 2004).*

Figure 5.1 shows that the frequency of pine caterpillar outbreak depend closely on the age of forest. For example, during the 17-year period, from 1987 to 2003, about 95% of pine caterpillar outbreaks happened to the forests aged from five to 16 years old. It means that age of forest was one of decisive factors to the pine

caterpillar outbreak in Thua Thien Hue province. The calculation of frequency of outbreak occurrence by forest age, we can see that the highest percentages of pine caterpillar outbreak found in pine forest from nine to 13 years old with 15.7%, 18.9%, 17.0%, 13.8%, and 11.3% respectively. It also can be seen from the Figure 5.1 that the occurrence of the epidemic was decided by the age of forest. The forests aged 10 years old had the highest frequency of epidemic occurrence, followed by the forest aged 11, 9, 12, and 13 years old. The forests at the age group five to eight or 14 to 16 have been experienced the epidemic but the frequency of the outbreak was not high. Whereas there was no epidemic occurred in the forests, which are younger than five years old and the older group (16 years old and above).

To test the affect of forest age on the epidemic occurrence in December, contingency table was used and the result is shown in the Table 5.2. The highest frequency of epidemic occurrence was resulted from the forest age level three (between 11 and 15 years old), followed by the forest age level two (between six and 10 years old). In the forest age level five (greater than 20 years old) the outbreaks have not occurred.

Table 5.2: The outbreak occurrence in December in different level of forest age.

Level of forest age -------years (level)----------	Number of epidemic occur	Total of observation
Less than 6 (level 1)	2 (10.6)	51
6 to 10 (level 2)	20 (10.6)	51
11 to 15 (level 3)	29 (10.6)	51
16 to 20 (level 4)	2 (10.6)	51
Greater than 20 (level 5)	0 (10.6)	51
Total	53	255

(Source: TTH DFP, 2004).

Note: numbers in parenthesis indicate the expected value.

The Pearson Chi-square (χ^2) value was 81.84 and it was significant at level 5% with four degree of freedom. It means that different forest ages resulted in

different frequency of pine caterpillar outbreak occurrence. Therefore, it can be concluded that forest age was one of the factors affecting the outbreak of pine caterpillar in Thua Thien Hue province. This result is useful for forestry scientists and forestry managers to make decision on pest management. The result suggested that the priority should be given to the pine forests aged from six to 15 years old, especially from nine to 13 years old.

Besides, the density of larvae in December related to the age of forest was shown clearly in Figure 5.2. The different level of forest ages have different density of larvae in December. These densities of larvae in each level of the forest age were more fluctuation due to the calculations were varied forest age, as well as the different years that the outbreaks were occurred or were not occurred.

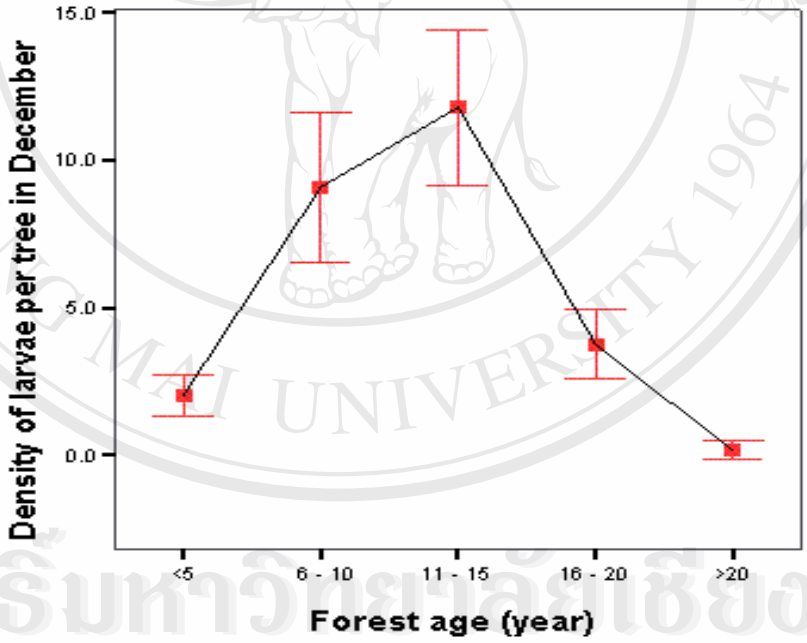

Figure 5.2: Distribution of larvae density in different level of forest age.
(Source: TTH DFP, 2004).
Note: Error bars show 95% confidence interval.

However, the lowest density of larvae was found in level five of forest age, and the highest density of larvae was found in level three of forest age. The differences were significant at least at level 5%. However, the difference of larvae

density between forest age level one and level four, and between level three and level four were not significant at level 5%.

5.1.3 The distribution of outbreak occurrence relating to month

Pine caterpillar outbreaks often occur in certain time of the year (Figure 5.3). Most of the outbreaks happened during the period from November to February. Interestingly, the time between December and January made up about 77% of the epidemic occurrences.

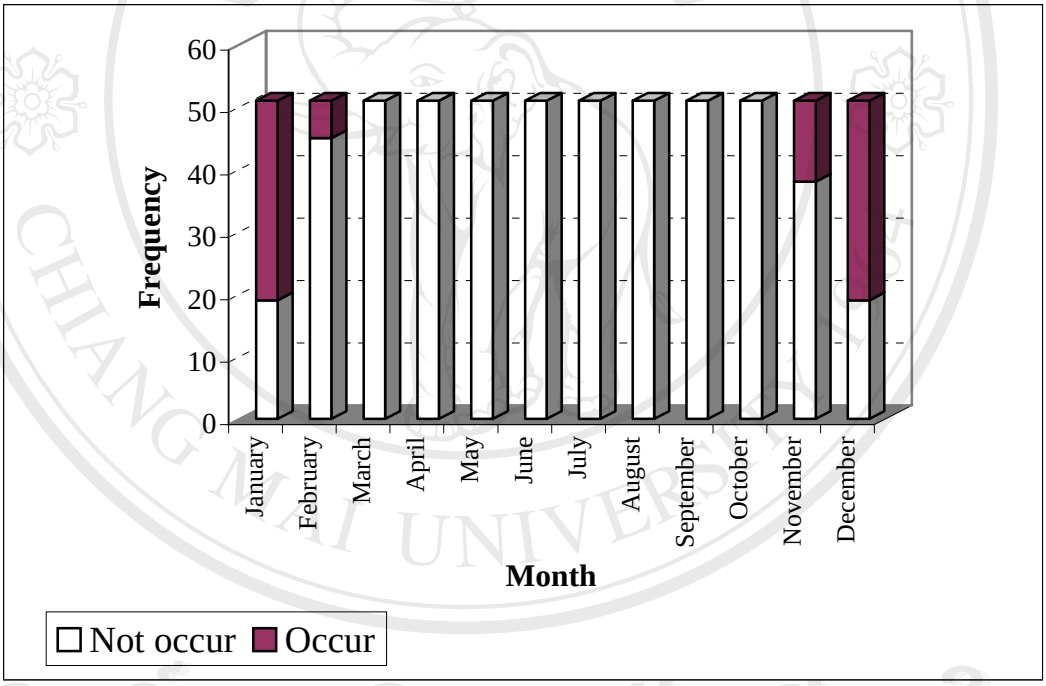

Figure 5.3: Pine caterpillar outbreak in different months.
(Source: TTH DFP, 2004).

Because the outbreaks usually occur in December and January, so we can use some weather factors recorded from June to November to predict the outbreak. This period (from June to November) accompanies with the third and the fourth generation of pine caterpillar in the year. These regenerations often cause the outbreak of this pest in Thua Thien Hue province (Dien, 1997).

5.2 The status of pine forest in Thua thien Hue province

5.2.1 The distribution of pine forest according to the functions of forests

In Thua thien Hue province particularly, and in Vietnam generally, afforestation projects have been conducted to increase the forest cover in uncovered hills and barren land. The main aim of the planted forests is to protect environment. Another benefit has been to supply wood and timber for construction, in-door furniture, and fire-wood. A part from these benefits, pine forests have very special and valuable benefits that they can produce resin and provide good landscape for tourism industry. The area of pine forest in Thua Thien Hue by benefit was shown clearly in Table 5.3.

Table 5.3: Area of classified pine forest based on its utility in different locations.

Location	Total	Utility of pine forest		
		Resin extraction	Landscape tourism	Wood supplication
	----------ha----------			
A Luoi	782.6	0	0	782.6
Hue city	245.6	245.6	0	0
Huong Thuy	2,241.7	2,074.2	145.7	21.8
Huong Tra	2,141.1	2,069.2	55.6	16.3
Nam Dong	48.0	48.0	0	0.0
Phong Dien	2,601.5	2,556.3	0	45.2
Phu Loc	1,953.1	1,877.9	0	75.2
Total	10,013.6	8,871.2	201.3	989.1

(Source: TTH-DFD, 2002).

Total area of pine forest was about 10,000 ha, which account for about 17% of total area of the plantation forests in the province. It was estimated that the total production of the pine forests in the province was about 495,368 m^3 (sub-FIPI, 1999). Although the volume of pine forests was high, the purpose of the forest was not to supply wood. They have been planted to extract resin, which has high export value.

About 88.6% of total pine forest areas in the province were the pine forests for resin extraction. In the province, about 89% of total pine forest areas and about 97% of pine forest for resin extraction were located in four districts (Huong Thuy, Huong Tra, Phong Dien, and Phu Loc). That is why these districts were selected to survey in this study. The pine forests for wood supply have been planted in A Luoi district. The forests for landscape tourism were located in Huong Thuy and Huong Tra districts where the Tombs of Nguyen Kings' Dynasty are located.

5.2.2 The distribution of pine forest by pine species

The pine species are determined by the goal of forest and it also relate to the pest and disease management. The area of pine forests by pine species in different location is shown clearly in Table 5.4. *P. merkusii* was a dominated species in the province. The species makes up about 90% of the total area of pine forests. In addition, the *P. merkusii* forest mainly concentrated in four districts and their main aim was resin extraction.

Table 5.4: Area of pine forest classified according to pine species in habitat.

Location	Total	*P. caribeae*	*P. Khaya*	*P. merkusii*
	----------ha----------			
A Luoi	782.6	0	782.6	0
Huong Thuy	2,241.7	21.8	0	2,219.9
Phu Loc	1,953.1	75.2	0	1,877.9
Nam Dong	48.0	0	0	48.0
Huong Tra	2,141.1	16.3	0	2,124.8
Hue city	245.6	0	0	245.6
Phong Dien	2,601.5	45.2	0	2,556.3
Total	10,013.6	158.5	782.6	9,072.5

(Source: TTH-DFD, 2002).

In Thua Thien Hue province, *P. merkusii* is usually planted forest for resin extraction. Other species that are also preferred and planted are *P. khaya*, or *P.*

caribeae. Each pine species normally accompanies the destroy of certain group of pests. *P. merkusii* forests mainly damaged by pine caterpillar named *D. punctatus Walker*. But other pine species, on the other hand, mainly damaged by sawflies, such as *Gilpinia murshalli*, *Diprion sp*. or pine caterpillar, which is known as different names, such as *D. kikuchii*, *Evetria duplana* (Duc, 2000). This study focused only on the outbreak of pine caterpillar named *D. punctatus Walker* in pine forest, especially in pine named *P. merkusii*.

5.2.3 The distribution of pine forest by the age and density of the forests

Besides pine species, the pine caterpillar outbreak in pine forests can be affected by the age and the density of the forests. The age of forests usually relate to the sources (quantity and quality) of food. The density of forest relates to the spread of epidemic when it occurs. The distribution of pine forests based on the age and the density of forest will give information about the vulnerability of the forest from the pine caterpillar outbreak. The distributions of area of pine forest based on the forest age and forest density are shown in Table 5.5 and Table 5.6 respectively.

Table 5.5: Area of pine forest classified according to forest age and location.

Location	Age of forest					Total
	<=5	6 to10	11 to15	16 to 20	>20	
	----------ha----------					
A Luoi	88.4	321.2	196.2	171.6	5.2	782.6
Huong Thuy	26.6	392.7	379.9	337.7	1,104.8	2,241.7
Phu Loc	168	85.6	977.2	616.3	106	1,953.1
Nam Dong	0	0	0	48	0	48
Huong Tra	0	192.4	1,243.9	283	421.8	2,141.1
Hue city	0	0	66.5	59.2	119.9	245.6
Phong Dien	468.3	419.5	831.8	693.1	188.8	2,601.5
Total	740.3	1,411.4	3,706.5	2,208.9	1,946.5	10,013.6

(Source: TTH-DFD, 2002).

Table 5.6: Area of pine forest classified according to level of forest density.

Location	Total	Density of forest (trees/ha)		
		< 700	700 – 1, 400	> 1,400
	ha			
A Luoi	782.6	0	781.6	1.0
Huong Thuy	2,241.7	413.9	1,665.4	162.4
Phu Loc	1,953.1	441.3	1,041.9	469.9
Nam Dong	48.0	0	48	0.0
Huong Tra	2,141.1	301.8	1,476.1	363.2
Hue city	245.6	0	109.5	136.1
Phong Dien	2,601.5	377.3	1,587.6	636.6
Total	10,013.6	1,534.3	6,710.1	1,769.2

(Source: TTH-DFD, 2002).

From the results discussed earlier above, the pine caterpillar outbreak usually occurs in the forest aged from five to 16 years old. If the forests was younger than five or older than 17 year old the outbreak may not occur. The result help to predict the challenges of pine forest in term of pine caterpillar in future. Because *P. merkusii* is the main species in almost all of area pine forests, and the area of the forests which are at the age of second to fourth level (from 6 years to 20 years old) accounted for about 74% of the total area of pine forests. The forest at third level of age, when had the highest frequency of pine caterpillar outbreak, occupied about 37% of the total pine forest area.

Similarly, the densities of forests also have affect on the pine caterpillar outbreak. The outbreaks usually occur with the forest where the density was more than 1000 trees/ha. The tables show the challenge of the pine forests since the density of most pine forests was from 700 trees/ha to more than 1400 tree/ha (about 85%).

It can be concluded that these conditions were flavor conditions for pine caterpillar outbreak when they met appropriate weather conditions. The probability of the outbreak and the level of damage is partly dependent on the structure (age and density) of forests.

5.3 The distribution of weather factors in Thua Thien Hue province

5.3.1 The distribution of temperature

Temperature and its fluctuation not only have affect on the growth rate of the pine forests (through affecting food resource of pine caterpillar) but also on the development of the pest. The distribution of temperature factors including average temperature, highest temperature, and lowest temperature, were shown in Figure 5.4. The data were collected in 17 years from three hydro-meteorological stations which represent the whole province. From the Figure 5.4 we can see that from April to October the temperature is higher and the lower temperature were from November to March of next year.

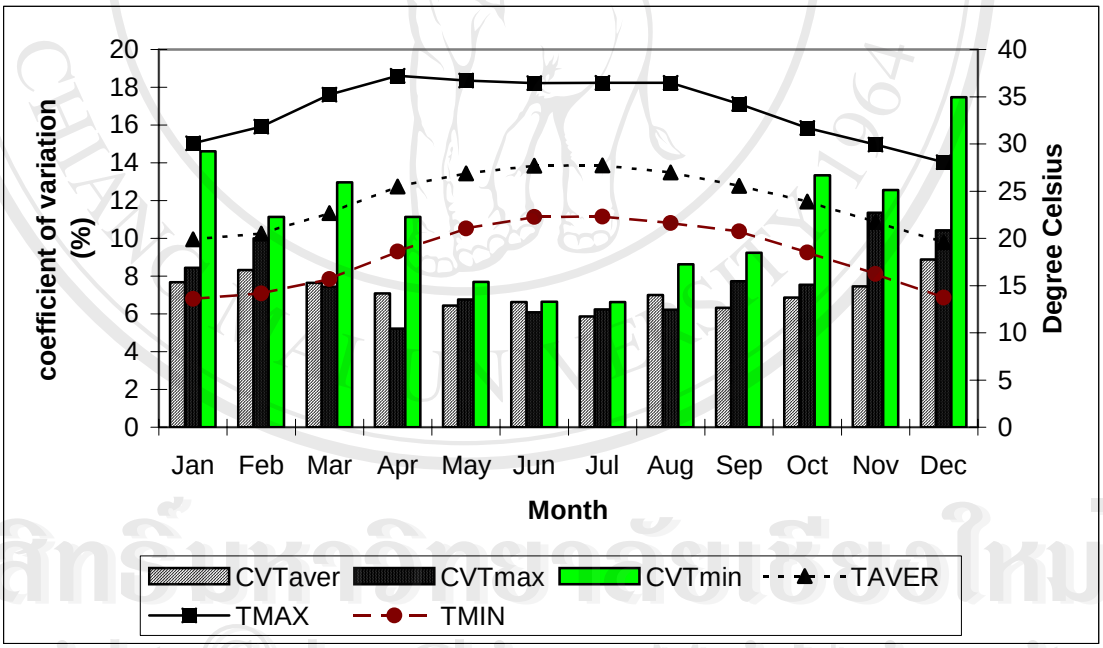

Figure 5.4: Distribution of temperature factors averaged over 17 years and their CVs. *(Source: Thua Thien Hue Meteorological station, 2004).*

Note: The columns/bars show the coefficient of variation (CV) of factors.

The dot/lines show the mean of temperature factors.

In which the highest temperature ranged from 28.1^{0}C to 37.2^{0}C, the average temperature was between 19.6^{0}C and 27.7^{0}C, and the lowest temperature was 13.6^{0}C to 22.3^{0}C. Moreover, the figure shows that the distribution of the three temperature factors reach a peak in April, and July for the highest temperature, and average and the lowest temperature respectively. But the lowest value was in December for highest and average temperature and in January for the lowest temperature.

However, the distribution of the coefficient of variation (CV) was quite different. The values are shown clearly in the Figure 5.4. Among the factors, we can see that the average temperature had the smallest fluctuation due to the value of CV was about 5.9% to 8.9%, while the fluctuation of the lowest temperature was larger, and the value of CV was about 6.6% to 17.5%. In addition, from May to September, the CVs of the three temperature factors were lowest compared with other months in the year. It means that in these months the fluctuations were small. Meanwhile, the CVs were too large from October to April. The highest fluctuation was found with the lowest temperature element, followed by highest temperature.

5.3.2 The distribution of humidity

The distribution of humidity and its coefficient of variation (CV) are shown in the Figure 5.5. The distribution of humidity was a reverse of normal distribution. The lowest air humidity was about 77% in July and the highest was about 92% in December. It reduced gradually from January to July after that it increased again and reached the maximum value in December. In general, the humidity in the province was suitable for the development of pine caterpillar because the threshold point for this pest was lower than 70% (Loanh, 1992). However, the lower humidity, less than 85%, was found from April to August. Under this condition, the development of pine caterpillar was limited (Loanh, 1992; DFP, 2001). That was one of the causes made low the larvae density in this period compared with other period in the year.

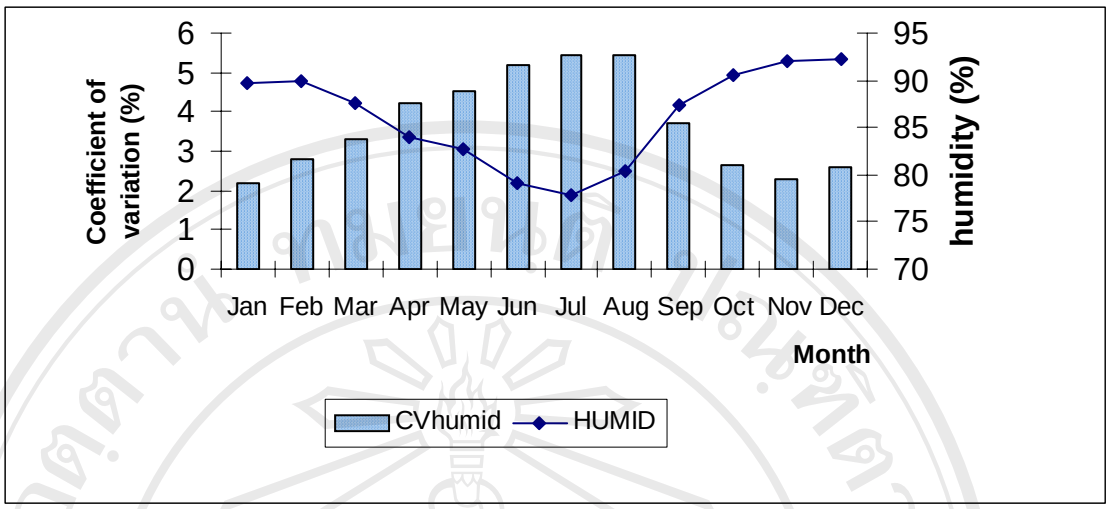

Figure 5.5: Distribution of average humidity averaged over 17 years and its CV.
(Source: Thua Thien Hue Meteorological station, 2004).
Note: CVhumid or the column/bar shows the CV of average humidity.
HUMID or the dot/lines show the mean of average humidity.

The Figure 5.5 also shows that the CV that looks like a normal distribution and its peaked in July. The fluctuation of humidity within a month was not too large because the CV was low ranging from 2.2% to 5.4% in January and July respectively. However, the larger fluctuations of humidity happened from April to August, However, the humidity kept stable from October to February.

5.3.3 The distribution of rainfall regime

The distribution of monthly total rainfall and number of rainfall days were shown in the Figure 5.6. The figure shows that the highest total rainfall occurred in October with about 939 mm, and the lowest total rainfall in March with about 55 mm. The total rainfall in the year concentrated in four months, from September to December, which made of about 71% of total rainfall in the year. However, the month December has the biggest number of rainfall days with about 21.6 days, and the lowest in April with about 11.8 days. The number of rainfall days was not too different among different months in the year. In another word, there was no evident relationship between the number of rainfall days and the total rainfall in a month.

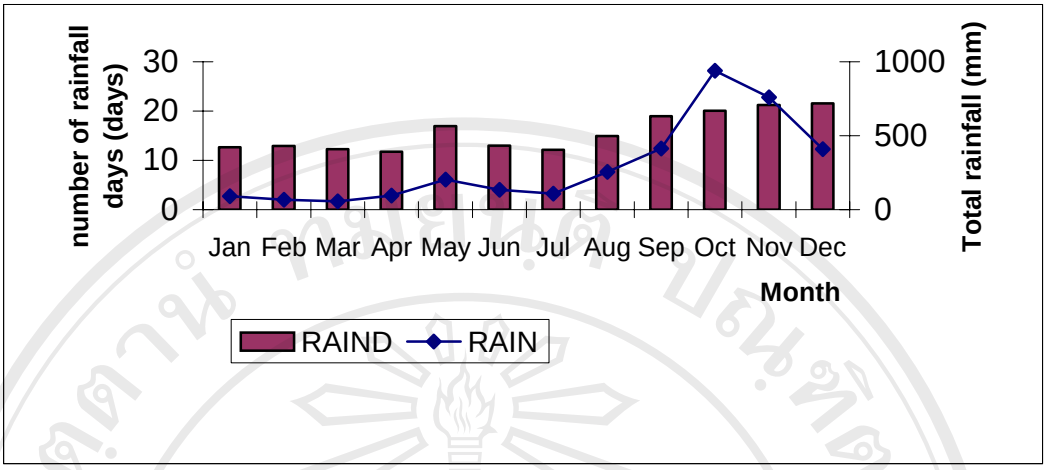

Figure 5.6: Distribution of total rainfall (RAIN) and number of rain days (RAIND) averaged over 17 years.

(Source: Thua Thien Hue Meteorological station, 2004).

The fluctuation of rainfall regime within a month which was represented by the coefficient of variation (CV) that was shown in Figure 5.7. The fluctuation of number of rainfall days was smaller than total rainfall. CV of number of rainfall days was between 21% and 45%, while this figure for factor of total rainfall was between 55% and 95%. The fluctuation of number of rainfall days was small compared to that of total rainfall but it was still quite higher than those of other factors such as humidity or temperature.

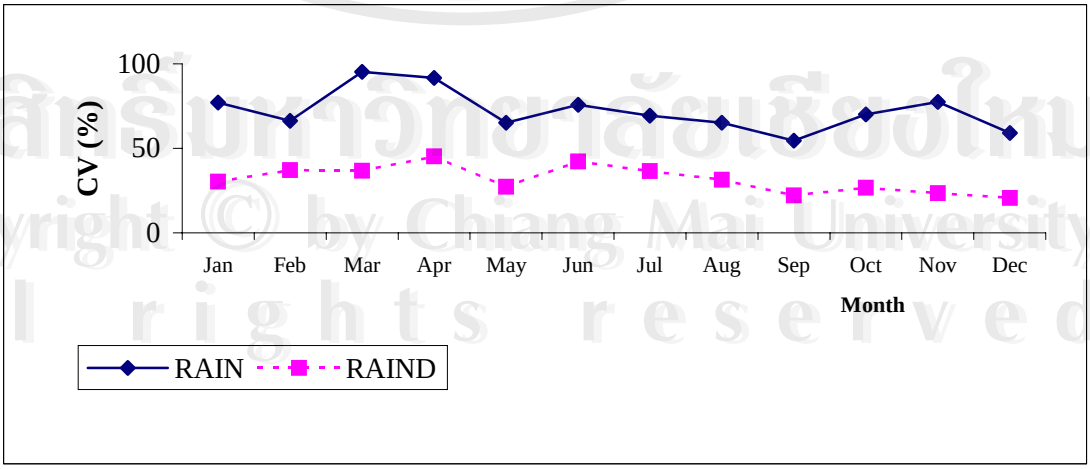

Figure 5.7: The CV of total rainfall (RAIN) and number of rain days (RAIND).

(Source: Thua Thien Hue Meteorological station, 2004).

5.3.4 The distribution of number of sunshine hours

Contrary to the humidity, the distribution of the number of sunshine hours looked like the normal distribution that reached the peak in July with about 217.4 hours and the lowest value in December with about 63.4 hours. The distribution of number of sunshine hours and its coefficient of variation are shown in Figure 5.8.

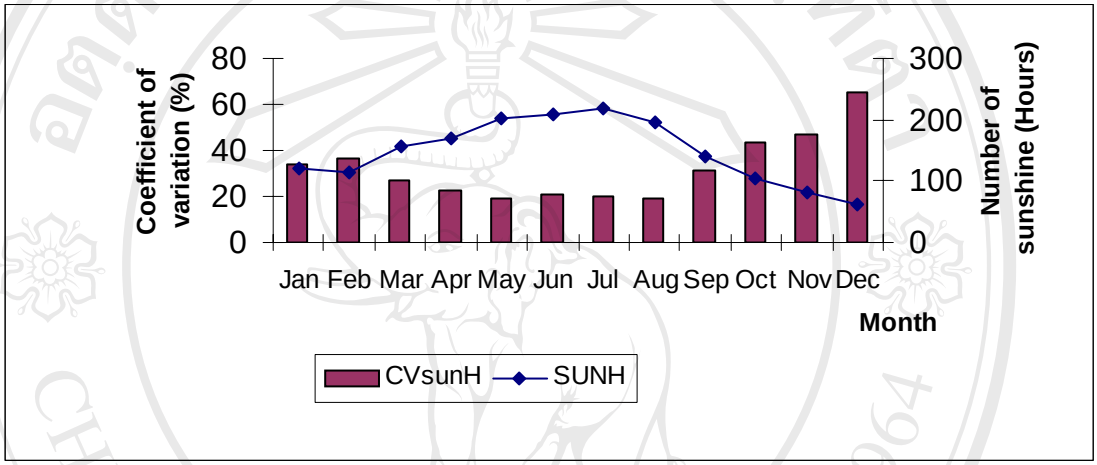

Figure 5.8: Distribution of number of sunshine hours averaged over 17 years and its CV. *(Source: Thua Thien Hue Meteorological station, 2004).*

Note: CVsunH or the column/bar shows the coefficient of variation.

SUNH or the dots/line shows the mean of number of sunshine hours.

The period from March to September had more sunshine hours. That was closely accompanied with the temperature in the year. Moreover, amount of sunshine hours during the period, from April to August, was more stable than those in other months because the value of coefficient of variation (CV) was low. From October to February the number of sunshine hours was more fluctuated.

From the distribution of weather factors, it can be concluded that, there were relationship between the development of pine caterpillar and some weather factors such as temperature or total rainfall or humidity. For example, when the temperature was high, the humidity was low and the number of sunshine hours was high the larvae density was low that the humidity is low and the number of sunshine is high the larvae

density is too low. This situation happened in the period from April to August. This finding agreed with the results reported by PIAWFR (1994) and Dien (1997).

However, the important step is how to use the relationship between weather factors in the year to predict the outbreak of pine caterpillar in December. Because it is obvious that the development of the pest related to the weather factors in certain period of time but they can be also determined by the development of the previous generations. If the weather factors are favorable for the development of the pest only in short time, the outbreak of the pest may not happen. However, if the weather factors remain in favorable conditions for a long time, it may cause the outbreak in future due to the productive capacity of this pest is too high. In addition, the outbreaks of pine caterpillar usually occur in December when the fourth generation of this pest are reach its peak population. The third and fourth generations of pine caterpillar started developing from June to February (Dien, 1997). It resulted in a high density of larvae (the fourth generation) in December and January that might cause the outbreak occurrence. It means that the weather factors from June to November may be considered good factors to predict the outbreak of pine caterpillar in December. The results of using the relationship between the pine caterpillar and some relative factors to develop some statistical models to predict the larvae density in December and the probability of outbreak occurrence of this pest will be discussed in next chapter.