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Effect of damaged pine needles on growth and development of pine caterpillar larvae

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Abstract Chinese pine caterpillar (*Dendrolimus tabulaeformis*) larvae were fed with pine needles of different degrees of damage to evaluate the effects of pine needles on the growth and development of larvae. The results showed that the nutritional index of the larvae declines after feeding on the damaged pine needlings. The lowest amount of food ingested and voided feces, the lowest nutritional index, slowest development, lightest pupae and most mortality were found in those pine caterpillar larvae fed with pine needles which were 50% damaged. The damaged pine needles significantly affected the population dynamics of Chinese pine caterpillars. The nutritional indices of larvae fed with 25% and 75% damaged pine needles were similar. The nutritional index of the dark morphs was higher than that of the tinted morphs, however, their mortality was lower than that

of the tinted morphs. This phenomenon was reversed at the later stage of development when the larvae were fed on 50% damaged pine needles.

Keywords damaged *Pinus tabulaeformis*, *Dendrolimus tabulaeformis*, color morph, growth and development

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1 Introduction

The Chinese pine caterpillar (*Dendrolimus tabulaeformis* Tsai et Liu.) (Zhao et al., 1999) belongs to the Lasiocampidae of the Lepidoptera. It is a major pest of Chinese pines and is found in Beijing, Hebei, Liaoning, Inner Mongolia, Gansu, Shanxi, Shandong, Shanxi, Henan, Hubei, Guizhou and Sichuan Provinces. The Chinese pine caterpillar not only endangers Chinese pine (*Pinus tabulaeformis*), but also Masson pine (*P. massoniana* Lamb.), lodgepole pine (*P. thunbergii* Parl.), Hua Mountain pine (*P. armandii* Franch.) and white skin pine (*P. bungeana* Zucc). Therefore, the prevention of occurrence and control of the Chinese pine caterpillar becomes a major mission in pine forest management (Hou, 1987; Chen, 1992).

In recent years, many scholars have studied the mechanism of the periodic eruption of the pine caterpillar from the relation between plants and herbivores and analyzed the effect of induced resistance of pines on the population of pine caterpillars. For example, Li et al. (1998) studied the characteristics of induced resistance of Chinese pine and its effect on ingested food, mortality and fecundity of *D. punctatus spectabilis* (Butler) (Li et al., 1998). Ge et al. (1997) reported that Masson pine produced the characteristics of induced resistance after it was endangered by Masson pine caterpillars, which affected the change in parameters of the Masson pine caterpillar population. In this study, we fed Chinese pine needles, damaged to different degrees, to Chinese pine caterpillar larvae to evaluate the effect of pine needles on their growth and development, in order to explain the natural characteristics of induced resistance of Chinese pine.

2 Materials and methods

2.1 Insect source

During ten days in the middle of April 2003, at the forestry center of Chang Shaoying village of Huairou County in Beijing, we collected a batch of third instar larvae after they overwintered and before they swarmed up the trees. We bred them indoors, selected healthy larvae with good growth and consistently warm bodies to use as experimental material.

2.2 Pine disposal and pine needle collection

In April 2003, we selected 14 Chinese pines with consistent growth conditions, which had been growing for about twenty years on the campus of Beijing Forestry University, adopted an artificial method to take off pine needles, largely two years old, to simulate an endangered form of overwintered larvae of the Chinese pine caterpillar. There were four ranges of damage, i.e., 0, 20%–25%, 45%–50% and 70%–75% (conveniently and consistently written below as 0, 25%, 50%, 75%). We used five Chinese pines as undamaged trees and selected three Chinese pines as damaged to different degrees. From these trees we took off needles from the top, middle and lower branches and the four cardinal directions and collected a certain amount of two year old needles within every range to use as the food source for the caterpillar every two days during the larval period of the Chinese pine caterpillar generation that had overwintered.

2.3 Larval feeding

The larvae of Chinese pine caterpillar were divided into dark morphs and tinted morphs following the method of Pang (1989), which divided the 2nd- to 5th-instar larvae of caterpillars into two groups, based on the presence of converse scalelike hair on the back of the body, and the dapple form and color of every body segment. The larvae of the tinted morph carrying converse scalelike hair on the back of the body were buff, the abdominal segments reversed from first to seven, each yellow dapple with a pronounced dumbbell form. The larvae of the dark morph carrying converse scalelike hair on the back of the body were ash black, had a dark yellow dapple and did not take on a pronounced dumbbell form. The larvae from 5th- to 6th-instar through ecdysis, lost their dumbbell form and dapple, but the color of the scalelike hair remained constant. In a biological and chemical cultivation box, (LRH-250A) manufactured by the Medical Treatment Equipment factory of Guangdong Province, the larvae of Chinese pine caterpillar of different morphs were fed fresh pine needles from every stated range of damage. The temperature was (27±1)°C, the ratio of light to dark was 15:9, the larvae were fed in finger form tubes with a size of 4 cm×10.7 cm, each finger form tube

held twenty larvae. Feeding from each of the four levels of needle damage was repeated 3 to 5 times and fresh needles were supplied every other day. The larvae were prevented from becoming pupae. We observed and recorded larval mortality and growth circumstance for each level of damage.

2.4 Measurement of nutritional effects on caterpillars fed with pine needles from different levels of damage

We first weighed the larvae before we fed them with fodder, put fresh needles into the finger form tubes, fed the larvae for two days and made the larvae accept the fodder. The first nutritional index was measured after two days. After this, it was measured every eighth day. The detailed steps are: before we started the experiment we weighed the larvae and pine needles, guaranteed enough pine needles for the larvae and put them into the finger form tubes to feed on the needles; every other day we weighed the larvae, the pine needles and voided feces, put completed needles and voided feces into an oven, kept at 80°C for 12 hours; afterward, the material was weighed again, using the Waldbauer formula to calculate approximate digestibility (AD), efficiency of conversion digested food (ECD) and efficiency of conversion of ingested (ECI) (WALDBAUER, 1964, 1968; Qing, 1987) food.

$AD = ((\text{amount of food ingested} - \text{amount of voided feces}) / \text{amount of food ingested}) \times 100\%$

$ECD = (\text{increased weight} / (\text{amount of food ingested} - \text{amount of voided feces})) \times 100\%$

$ECI = (\text{increased weight} / \text{amount of food ingested}) \times 100\%$

$\text{Relative growth rate (RGR)} = \text{increased weight} / (\text{average weight} \times \text{time of food ingested})$

3 Results and analysis

3.1 Amount of food ingested by larvae

The substance of induced resistance in damaged Chinese pine had a function of anti-feeding and deterrence to Chinese pine caterpillars. The caterpillar larvae were fed with pine needles damaged to different degrees to evaluate the effect on the amount of food ingested. The results showed that the dry amount of food ingested each day increased along with their development. The amount of food ingested by the dark morphs was higher than that of the tinted morphs when fed pine needles, classified into the four degrees of damage, but when larvae were fed with 50% damaged pine needles, the amount of food ingested by larvae of the dark morphs and that of the tinted ones was similar.

In April, the caterpillar larvae had just started the stage of food ingestion. With needles from the four damage levels, the average daily amounts of food ingested by the dark morphs were as follows: 0.060,7±0.004,6 g, 0.046,9±0.003,9 g, 0.039,4±0.007,2 g and 0.049,2±0.004,3 g; that of the tinted

morphs: $0.050,8 \pm 0.005,2$ g, $0.038,6 \pm 0.005,7$ g, $0.029,6 \pm 0.005,5$ g and $0.042,4 \pm 0.001,6$ g. When both kinds of morph larvae were fed with undamaged pine needles, the amount of food ingested was appreciably higher. When they were fed with 50% damaged pine needles, the amount of food ingested was considerably less. The amount of food ingested was similar when they were fed with 25% and 75% damaged pine needles. But the amount of food ingested with pine needles from each damage level did not differ significantly. From analysis of variance we obtained the F values which were, statistically, not significant within the damage levels for each kind of morphs ($F_{\text{dark}} = 2.917 < F_{0.05} = 4.07$, $F_{\text{tinted}} = 3.341 < F_{0.05}$).

The amount of food ingested by larvae increased quickly along with their growth and development. The variation on May 3 coincided with that in April. The difference was significant within damage levels ($F_{\text{dark}} = 4.873 > F_{0.05}$, $F_{\text{tinted}} = 4.301 > F_{0.05}$). Using LSD tests in multiple comparisons, the larvae of both kinds of morphs showed that the amount of food ingested of undamaged needles was significantly different when compared with 50% damaged needles, but that differences with 25% and 75% damaged needles were not significant. After May 10, the larvae of both kinds of morphs showed that they had the most amount of food ingested when fed with undamaged pine needles; in second place came the 75% damaged pine needles. The smallest amount of food ingested was from the 50% damaged pine needles, followed by the amount ingested from the 25% damaged pine needles. From the analysis of variance, we observed significant differences within damage categories ($F_{\text{dark}} = 4.266 > F_{0.05}$, $F_{\text{tinted}} = 5.509 > F_{0.05}$). Also, on May 18, the differences were significant within damage levels ($F_{\text{dark}} = 4.100 > F_{0.05}$, $F_{\text{tinted}} = 4.379 > F_{0.05}$). Multiple comparisons by means of LSD tests show that the amount of food ingested from undamaged needles by the larvae of the two kinds of morphs was significantly different from that of the 50% damaged pine needles, but was not significantly different from the amounts ingested from the 25% and 75% damaged pine needles.

From Fig. 1 it can be seen that the amount of food ingested by larvae from undamaged pine needles was larger than that from damaged pine needles. The amount of food ingested fed from 50% damaged pine needles was the smallest among all the food types. This shows that moderately damaged pine needles were less palatable to Chinese pine caterpillars. The amount of food ingested from pine needles of different degrees of damage took on a certain regularity: the amount of food ingested from undamaged pine needles > that from 75% damaged needles > that from 25% damaged needles > that from 50% damaged needles.

3.2 Amount of voided feces

The various amounts of voided feces corresponded with the amount of food ingested. The dry amount of feces, voided by larvae, gradually increased daily along with their growth

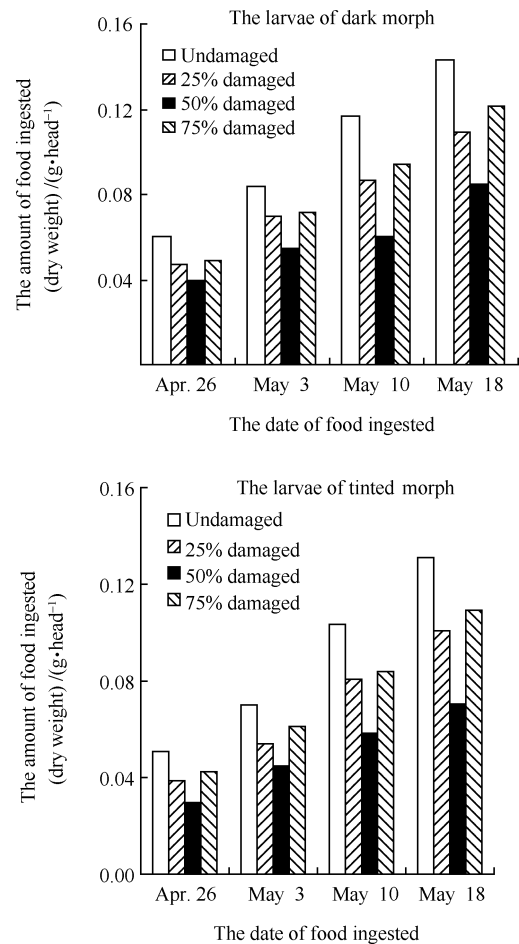


Fig. 1 Changes of food ingested by *Dendrolimus tabulaeformis* fed with pine needles damaged to different degrees

and development. The amount of voided feces of the dark morphs was higher than that of the tinted ones when they were fed with four kinds of damaged pine needles. The amount of voided feces, when fed with undamaged pine needles, was larger than that when fed with damaged pine needles, but when fed with 50% damaged pine needles, the amount of voided feces was always the smallest (Fig. 2).

In April, there was no discrepancy between the amount of voided feces of the two kinds of morphs, fed with pine needles of different degrees of damage. When the larvae were fed with undamaged pine needles, the amount of voided feces was appreciably larger. Again, when fed with 50% damaged pine needles, the amount of voided feces was appreciably less. But an analysis of variance indicated that the differences within the levels damage were statistically not significant ($F_{\text{dark}} = 3.048 < F_{0.05} = 4.07$, $F_{\text{tinted}} = 3.046 < F_{0.05} = 4.07$).

The amount of voided feces increased quickly along with growth and development. The variation in the trend on May 3 was the same as that in April; the differences were significant within levels of damage ($F_{\text{dark}} = 4.333 > F_{0.05}$, $F_{\text{tinted}} = 4.389 > F_{0.05}$).

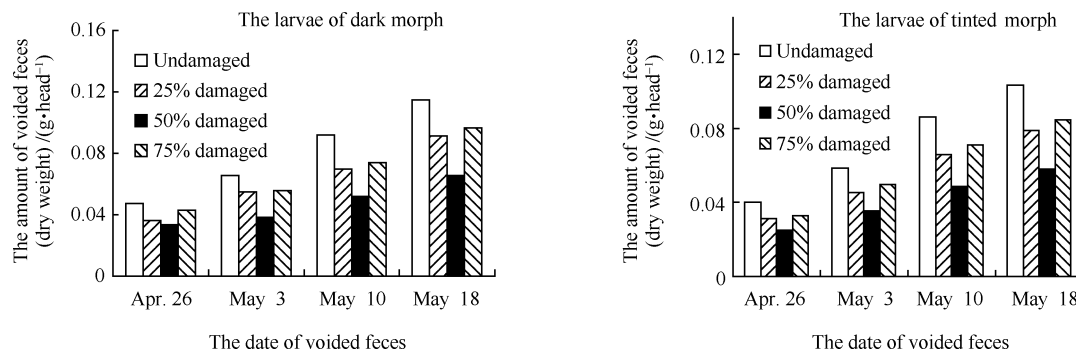


Fig. 2 Changes of voided feces of *Dendrolimus tabulaeformis* fed with different damaged pine needles

Again, multiple LSD comparisons of the larvae of both kinds of morphs showed that the amounts of voided feces, when the larvae were fed with undamaged pine needles, were significantly different from that when fed with 50% damaged pine needles, but there were no significant difference with the 25% and 75% damaged pine needles. After May 10, the larvae of both kinds of morphs showed that they voided the greatest amount of feces when fed with undamaged needles. At the same time, they had the smallest amount of voided feces when fed with 50% damaged needles. Analysis of variance showed the differences within damage categories were significant ($F_{\text{dark}} = 5.137$, $F_{\text{tinted}} = 4.178$). The variation in the trend on May 18 agreed with the trend on May 10; the differences were significant within levels of damage ($F_{\text{dark}} = 4.127$, $F_{\text{tinted}} = 4.89$). From multiple LSD comparisons, we conclude that the amount of voided feces when fed with undamaged pine needles was significantly different with that of 50% damaged pine needles, but there were no significant differences with that of 25% and 75% damaged pine needles.

After the caterpillars took pine needles of different degrees of damage, the variation each day in the amount of voided feces showed the following trend: the amount of voided feces from undamaged pine needles > that from 75% damaged needles > that from 25% damaged needles > that from 50% damaged needles.

3.3 Larval digested coefficients

3.3.1 Effect on AD

The wasting results of the larvae of different morphs, after the caterpillars were fed with pine needles of different degrees of damage, are shown in Table 1. The larval AD of both the dark and the tinted morphs declined with increasing age of the pine needles. The reason may be that older pine needles contain less water, have more coarse fibres and coarse ash manifold so that food quality deteriorates. Insects with chewing mouthparts cause AD to decline for they can feed off more coarse-fibres (Qing, 1987). The larval AD of both kinds of morphs was at a maximum when fed undamaged

pine needles and was at a minimum when fed with 50% damaged pine needles. Given the four levels of damage, along with larval growth and development, the AD of the dark morphs was lower than that of the tinted morphs when fed 50% damaged pine needles, but the difference was not significant. At other levels of damage, the AD of the dark morphs was higher than that of the tinted ones. Analysis of variance shows that the difference within damage levels of the tinted morphs was significant ($F = 4.464 > F_{0.05} = 3.490$). The differences within damage categories of the dark morph was even significant at the $\alpha = 0.01$ level ($F = 7.249 > F_{0.01} = 5.953$). The AD of the larvae decreased considerably when fed with 50% damaged pine needles compared with undamaged pine needles. This difference became more pronounced with ingested food. On April 29 when we weighed the larval AD of the dark morph, fed with 50% damaged pine needles, there was a 35.74% reduction compared with the AD of larvae fed with undamaged pine needles. For the tinted morph, the reduction was 28.46%. By May 18, the larvae of both kinds of morph were reduced respectively by 62.71% and 45.48%. It was very apparent that the dark morphs suffered a larger reduction in food quantity. The larval AD of the dark morph declined more because it has a weak kind of adaptability and resistance to conditions of under-nourishment.

Table 1 Changes in approximate digestibility of *Dendrolimus tabulaeformis* in different developmental periods and damaged pine needles

Morph	Damaged degrees	AD/%			
		April 26	May 3	May 10	May 18
Dark morph	Undamaged	33.10	32.05	26.98	24.62
	25% damaged	29.41	24.17	21.58	18.45
	50% damaged	21.27	14.18	12.28	9.18
	75% damaged	31.44	26.82	22.34	20.36
Tinted morph	Undamaged	27.90	25.96	21.37	19.59
	25% damaged	23.04	21.16	17.30	15.95
	50% damaged	19.96	13.79	13.34	10.68
	75% damaged	24.86	22.32	18.07	17.61

3.3.2 Effect on ECD

The ECD of the caterpillars increased gradually along with the growth and development of the larvae. The variation in the trend of larval ECD of both kinds of morphs was similar to that of AD. Both showed that the ECD of larvae, fed undamaged pine needles, was the largest, and the ECD of larvae that were fed 50% damaged pine needles was the smallest each time. The ECD of the dark morph larvae was lower than that of the tinted morph larvae when fed with 50% damaged pine needles. The larval ECD of the dark morphs was higher than that of the tinted morphs when fed with the other damaged pine needles. Analysis of variance showed that the differences within levels of damage of the dark morphs were highly significant ($F=9.783>F_{0.01}=5.953$). The differences were also significant within levels of damage of the tinted morphs ($F=4.449>F_{0.05}=3.490$). The dark morphs exhibited a greater effect. The ECD of larvae fed with 50% damaged pine needles lost more weight. The ECD of larvae fed with 25% and 75% damaged pine needles was lower than that of larvae fed with undamaged needles, but there was no discrepancy between the 25% and 75% kind of damaged needles. The ECD of larvae fed with 75% damaged needles was slightly higher than that of larvae fed with 25% damaged needles. The ranking of ECD is as follows: the ECD with undamaged pine needles > ECD with 75% damaged needles > ECD with 25% damaged needles > ECD with 50% damaged needles.

3.3.3 Effect on ECI

The ECI did not change much with the growth and development of larvae. The ECI of larvae fed with undamaged pine needles was about 10%, that of larvae fed with 25% and 75% damaged pine needles were slightly lower, but there were no significant differences. The ECI of larvae fed with 50% damaged pine needles declined relatively more, to about 7%. The ECI of the dark morphs was relatively higher than that of the tinted morphs. The maximum ECI of larvae

fed undamaged pine needles was 11.85%, for tinted morphs it was 10.97%. In contrast, the ECI of larvae of dark morphs fed with 50% damaged pine needles was lower at 7.65%, than that of the tinted morphs at 8.29%. A comparative analysis showed that the ECI with undamaged pine needles > that with 75% damaged needles > that with 25% damaged needles > that with 50% damaged needles. This explains why Chinese pine caterpillars can effectively utilize and transform undamaged pine needles because it is to their advantage to use the undamaged pine needles as foodstuff. It is disadvantageous to digest, transform and utilize foodstuff from damaged pine needles.

3.4 RGR

The larval RGR declined gradually along with their growth and development, with the RGR of the dark morphs slightly higher than that of the tinted morphs. In contrast, the RGR of the dark morphs was slightly lower than that of the tinted morphs when they were both fed with 50% damaged pine needles. This may be because this sort of digestion and utilization lead their bodies to accumulate less of the nutritional substance when they are fed with 50% damaged pine needles and therefore the RGR declines. The larvae of both kinds of color morphs showed that the RGR of larvae, when fed with undamaged pine needles, was the largest, that fed with 50% damaged pine needles the lowest. The RGR of larvae fed with 25% and 50% damaged pine needles did not show any statistically significant difference. The RGR of larvae fed with 75% damaged pine needles was slightly higher than that of larvae fed with 25% damaged needles. From Fig. 3, it can be seen that the RGR of larvae fed with 50% damaged pine needles was lower than that of larvae fed with other damaged pine needles. This indicates that moderately damaged pine needles impose the greatest restraint on larval growth of Chinese pine caterpillars. The differences were not significant within damage levels ($F_{\text{dark}}=2.872<F_{0.05}=3.490$, $F_{\text{tinted}}=2.114<F_{0.05}=3.490$).

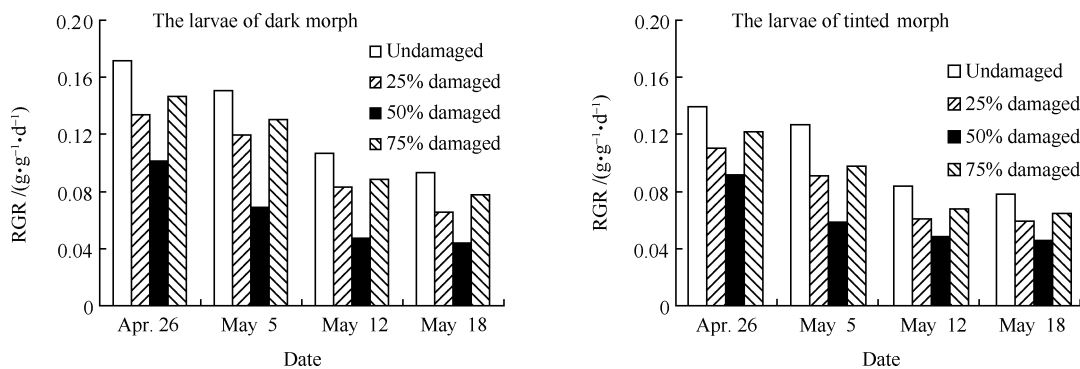


Fig. 3 Changes of RGR of *Dendrolimus tabulaeformis* fed with different damaged pine needles

3.5 Larval mortality

When Chinese pine caterpillar larvae were fed with pine needles of different degrees of damage, it had some effect on mortality. Table 2 shows that the mortality of larvae fed with undamaged pine needles was lower than when fed with damaged needles. In the initial stage of food ingested by larvae, mortality did not show any significant differences when they were fed with the four kinds of damaged pine needles; the mortality of dark morphs was very small and lower than that of tinted morphs. The mortality of dark morphs fed with undamaged pine needles was only 2%, that of tinted larvae reached 20%. Mortality increased with larval growth and development; larvae fed with 50% damaged pine needles had the highest mortality, those fed with undamaged pine needles the lowest. In contrast, at later stages of food ingestion, the mortality of dark morphs became lower than that of tinted morphs when they were both fed with 50% damaged pine needles. In the course of food ingestion, the mortality of larvae fed with 25% damaged pine needles was slightly higher than that of larvae fed with 75% damaged needles. Based on analysis of variance, the difference was not declared significant within levels of damage ($F_{\text{dark}}=0.811$, $F_{\text{tinted}}=1.248$). The order of ranking mortality shows that the mortality of larvae fed with 50% damaged pine needles > that with 25% damaged needles > that with 75% damaged needles > that with undamaged needles.

Table 2 Change of mortality of *Dendrolimus tabulaeformis* at different development periods and damaged pine needles

Morph	Damaged degrees	Mortality /%			
		April 26	May 5	May 15	May 25
Dark morph	Undamaged	2	7	10	31
	25% damaged	5	13	20	40
	50% damaged	6	14	39	67
	75% damaged	4	10	17	35
Tinted morph	Undamaged	20	27	29	42
	25% damaged	25	37	41	49
	50% damaged	28	41	47	60
	75% damaged	21	35	40	44

3.6 Effect on weight of pupae

After the caterpillar larvae pupated, their weight also changed. The weight of the pupae fed with 50% damaged pine needles was the lowest, when fed with undamaged pine needles the weight was the greatest. The difference in the weight of pupae was significant. Multiple LSD comparisons show that the weight of pupae fed with undamaged needles was significantly different from that with 50% damaged needles, but there were no significant differences with 25% and 75% damaged pine needles. Ranking the pupae by weight show that the weight of pupae fed with undamaged pine needles ((1.971,6±0.279,1)g) > that when fed with 75% damaged needles ((1.675,3±0.082,0)g) > that when fed with 25% damaged needles ((1.522,8±0.066,9)g) > that when fed with 50% damaged needles ((1.279,2±0.023,7)g).

The damaged pine needles had a great effect on the weight of pupae, especially on the weight of pupae fed with 50% damaged pine needles, which suffered the greatest effect. Their weight was 36.72% lower than that of pupae fed with undamaged needles. There was close correlation between the weight of pupae and fecundity: the heavier the weight of the pupae, the greater their fecundity. In contrast, the higher the force of procreation, the lower it was (Chen, 1992). The weight of pupae fed with damaged pine needles was relatively low. This necessarily led to reduced fecundity and procreation and as a consequence the size of the population also declined.

4 Conclusions and discussion

4.1 Conclusions

1. When Chinese pine caterpillar larvae were fed with damaged pine needles, compared with being fed undamaged needles, the amount of food ingested declined, the amount of voided feces also declined, lighter pupae emerged, greater mortality was exhibited and the AD, ECD and ECI indices were lower. The most prominent decline in the nutritional index occurred when the larvae were fed with moderately damaged pine needles (the 50% level of needle damage). The highest nutritional indices and the best development were evident when the larvae were fed with undamaged pine needles; there was no discrepancy between the nutritional indices of larvae fed with 25% and 75% damaged pine needles. The effect of the differently damaged pine needles was statistically significant for the pine caterpillars. This showed that the pine, to a certain extent, can limit damage; the ability of pine to defend itself was strongest when it lost needles to moderate damage. This defense ability was weak when it lost needles to severe damage. There were no statistically significant differences in the effect on growth and development of the pine caterpillar.

2. In the course of food ingested, the nutritional index of the dark morphs was higher than that of the tinted morphs and the mortality was lower. The larvae of dark morphs had a stronger affinity for digestion and absorption, they ingested large amounts of food, accumulated more nutritional substance and had a greater RGR. These results are in agreement with previous studies.

3. When the larvae of different morphs were fed with pine needles of different levels of damage, there were differences in the effect on their growth and development. When they were fed with undamaged, 25% and 75% damaged pine needles, the nutritional index of the dark morphs was higher than that of the tinted ones. However, this phenomenon was reversed at the later stage of taking 50% damaged pine needles. The mortality of the dark morphs was higher than that of the tinted morphs. These showed that the larvae of the dark morphs had a kind of adaptability and a feeble defense to adverse conditions (such as increased secondary

metabolites, declining nutritional substance).

4.2 Discussion

Ge et al. (1997) found that the weight of larvae (larval instars, old instars) and pupae decreased, mortality increased, the force of procreation declined and the activity of two kinds of detoxification enzymes swelled in the body of Masson pine caterpillar when they were fed with damaged pine needles. The authors showed that damaged pine needles were disadvantageous to larvae in their growth and development, digestion, translation and utilization of nutritional substances. The effect of the different levels of damage in pine needles were significantly different on Chinese pine caterpillars. This partly explained the fact that an induced resistance substance of damaged pine triggered a reaction as a defence against attacks by caterpillars. But this effect also led to a declining nutritional index, higher mortality and lighter pupae, which necessarily led to a reduction in fecundity and a decline in the force of procreation. This scenario also predicts that the size of the next generation will stabilize or decline. Especially, when the larvae were fed with 50% damaged pine needles, or worse, the nutritional index of the caterpillar declined, mortality increased and pupae became lighter, Chinese pine could resist the danger of pine caterpillars with its own defence system. When the larvae were fed with needles, damaged to a lesser extent, the food ingested swelled again, and the ability to resist weakened, which showed that Chinese pine has a functioning defence system confined to a certain range of damage levels, within which it can resist caterpillar attacks by adjusting its own chemical composition, altering its nutritional substance and controlling the size of the caterpillar population. Earlier studies show that dark morphs have greater adaptability, an increased rate of weight gain, heavier female pupae and a stronger propagative ability. These are the important factors which determine the rate of increase in the population of Chinese pine caterpillars (Pang, 1989). The authors of the study also showed that when the larvae of dark morphs received their largest boost fed with damaged pine needles and when the Chinese pine had strong resistance, the next caterpillar generation would also be affected accordingly. To summarize, we can conclude that Chinese pine caterpillar fed with damaged pine needles should have an effect on the size of the population, that the size of the next generation should stabilize or decline and that it wasn't easy for a disaster to break out. Over long time periods, Chinese pines have reduced the pressure of caterpillar populations along with weak induced resistance of the pines. The size of the caterpillar population could rise again and cause periodic outbreaks of Chinese pine caterpillars. Therefore, for reasons of prevention and cure, we should adequately consider the characteristics of induced resistance of our pine, reduce reliance on chemical prevention and cures, reduce the cost of prevention and cure, and proceed to ecotypic adjustment and control.

Recently, many studies have demonstrated that plants suffer stress of entomoc food intake, which occurs in various aspects of physiological metabolism. For example, with the key enzymatic vigour of a secondary approach heightened and a secondary substance increase, the efficiency of photosynthesis, respiration and the composition of protein changed. The metabolism of protein, lipid and phenenes was especially able to change profoundly. These changes should directly or indirectly affect insect living with plants (Kang, 1995). After Chinese pines were damaged, changes in the nutritional and secondary substances should have occurred to different degrees. This should have been manifested in a decline in the amount of sugar, protein, amino acids and fatty acids. These substances are important to pine caterpillars; the amount of each kind of secondary substance, such as tannins, alkaloid, phenenes and erpenoids increased, which are detrimental to the growth and development of pine caterpillars (Ge et al., 1997; Li et al., 1998). In the case of Chinese pine needles, damaged to different degrees, a future investigation should be conducted on how to change and affect larval growth and development, a subject closely related to aspects reported here by us.

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