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Agriculture Master's Degree Thesis

Damage by Lycorma delicatula and chemical control in vineyards

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2010. Feburary.

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Damage by Lycorma delicatula and chemical control in vineyards

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This thesis is accepted as Myung-Gyu Song's Agriculture Master's degree thesis.

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I. Introduction (P.1)

Though the net area encompassed by South Korea's vineyards is not growing as fast as the average growth of the area of the rest of the world's vineyards, organic grape production in Chung-Buk has been increasing due to increasing marginal benefit.. Chung-Buk's organic vineyard area dramatically increased from 0.6ha in 2006 to 196.3ha in 2008, from 1 vineyard in 2006 to 636 vineyards in 2008. (Kim, 2009; Chungbuk Grape Research Institute, 2008). However, this increase in organic vineyards caused increasing damage from pests, and there was need of control methods for sporadic pests. Among sporadic pest, the spotted lanternfly has been causing the most serious damage among vineyards.

The spotted lanternfly (Lycorma Delicatula) causes damage to vineyards by sucking directly on grapevines and causing sooty mold disease with their excretion. These damages are more serious in organic vineyards than in traditional vineyards. However, there wasn't sufficient research on either the ecology of the Spotted Lanternfly inside the vineyard, or on the damage that the Spotted Lanternfly causes by sucking sap from grapevines.

Therefore, this thesis tries to provide basic information for vineyards to control spotted lanternflies in the future by researching damage caused by the spotted lanternfly as well as its ecology and different methods for controlling this pest.

II. History of Research (P.2-3)

The spotted lanternfly (Lycorma Delicatula) belongs to the order of Hemiptra and family of Fulogoridae. They inhabit China, Japan, India, Vietnam and other southern Asian countries. In Korea, Limois emelianovi Oshanin (heu-zo Ggot-mae-mi), and Ggot-mae-mi (Lycorma Delicatula) are observed. Instead of finding places to hide, Lycorma Delicatula is generally found in exposed places because they have ways to survive without hiding. Lycorma Delicatula can jump and camouflage with their forewings. They also has a red warning color in its hindwings that warns predators that it is toxic. (Xue and Yuan, 1996).

Lycorma Delicatula is a subtropical pest that is from the hot region of southern China and southeast Asia. It was first observed in Cheonan, Korea, in 2004 Korea, Cheonan, in 2004. After 2006, its population began to dramatically increase. In 2007, it was observed in Seoul, Goyang, Incheon, Cheonan, Cheongju, and Jeongeup, and in 2008, it was observed in Gyeonggi-do (state) Paju, Gapyeong, Gwangmyeong, Sungnam, Gunpo, Anseong, Chungnam (state) Gongju, Yeongi, Asan, Chung-buk (state) Chungwon, Jincheon, Boeun, Gangwon (state) Chuncheon, Won-ju, Gyeong-buk (state) Yeongchun. This dramatic increase happened because Lycorma Delicatula can stay alive during winters in Korea. Lycorma Delicatula was originally an invasive species from China but it is naturalized in Korea now. (Han et al, 2008) Before 2008, Lycorma Delicatula was called the Scarlet winged- Ggot-mae-mi, however as they became the most dominant species among Ggot-mae-mi, it was renamed Ggot-mae-mi (Han et al, 2008)

There is existing research in South Korea on Lycorma Delicatula's form during the different stages of development, as well as research on the time spent in each stage as a nymph. There are also studies on how the five chemicals (including Deltamethrin) used to control Lycorma Delicatula's population affect 38 different species of trees and three species of herb."

In China, there are studies on 23 species of host plants for Lycorma Delicatule, including the tree of heaven (Xiao, 1991).

Lycorma Delicatula is considered a pest, but it was also used as medicine. Cantharidin (Feng et al, 1988) and Yohimbine, and Beta-Ajmalicin (Xue and Yuan, 1996) were observed in Lycorma Delicatula. Cantharidin was used in China and Europe as a medicine for long time, because of its anticancer properties (Feng et al, 1998). In Wonsec – insect medicine dictionary says that Lycorma Delicatula can be caught in the fall, killed in boiling water and dried in sun to treat extravagated blood, toxin, inner stomach lump, ravy bite (Choi, 2002).

Even though Lycorma Delicatula can be used as a medicine but due to dramatic increase in population, they are causing serious damage in vineyards and that’s why this research is being conducted.

III. Materials and Methods (P.4-9)

1. Population Research

During July to Agust in 2008 and 2009, the team traveled through different routes by car in Chung-Buk state. They observed host plants of Lycorma Delicatula like hyun poplar (Populus tomentiglandulosa), grapevine, and trees of in order to determine the number of nymphs and imagoes of Lycorma Delicatula per tree, as well as the overall population of Lycorma Delicatula. When there was a vineyard in the town, the observation was divided into inside the vineyard and around the vineyard. If there was no Lycorma Delicatula observed inside the vineyard, the vineyard was re-checked from October to November 2008.

2. Damage Research

Observation of the damage cause by honeydew was done during the harvesting period from 2007 to 2009 in vineyards in Chungju, Chungwon, and Chunan. Research into the financial damage caused from honeydew was done in vineyards from 2008 and 2009. Salability research was done per harvest during harvest season. In the case of organic vineyards in Chung-buk Chungju yongam, the salability research was divided depending on whether they used the cover for the grape or not. Salability research was done by comparing vineyards with sooty mold damage to those that didn't have it. In the case of traditional vineyards, the team visited 4 vineyards in the harvesting period and surveyed the usage of cover, the harvest method and the salability (amount that could be used).

3. Research on the Development of Grapevine

Grapevines were planted and raised from cutting slips with equal amounts of water in insect- proofed seed pots sized 100x60x45cm. The cutting slips were taken in May. Before the harvest, the height, stem length, stem thickness, average leaf length, and average leaf width of grapevines were measured. After measuring, the team placed 3 Lycorma Delicatula nymphs of some grapevines, four on other vines, and five on others. After ten days, they replaced the nymphs with imagoes.

4. Life cycle of Lycorma Delicatula in the Vineyard and research on the Number of Eggs per Egg Sac

The team collected Lycorma Delicatula's eggs in Chunju-si Yongam-dong during winter and observed them in quarantine. The form of each nymph was observed at 10 A.M in an insect-proofed green house from April to May. The amount of nymphs and the nymph's development period were observed based on Picture 1. The research on the number of eggs per egg sac was done by collecting 30 egg sacs each from Pinus strobus (White pine), Acer palmatum (Maple), Styrax japonica (Japanese Styrax), and Chaenomeles sinesis (Quince), and 90 egg sacs from Vitis labrusca (grapevine). The number of eggs was then checked.

5. The Effect of temperature and Light on the Hatching of Eggs

Experiment were conducted on the hatching of eggs that were collected in December in Vineyard. Eggs were placed in a plant culture dish sized 100mm in diameter and 40mm tall. Filter paper was put on top of the plant culture dish, and 50 Lycorma Delicatula eggs were placed on top of the filter paper. In order to research hatching conditions, eggs were first placed in different boxes of temperatures .... degrees. The eggs were kept in those boxes for either 0, 5, 10, 15, or 20 days. They were then transferred to incubators with temperatures of ... degrees.The Process was repeated three times on plant culture dishes and the amount of hatching was recorded everyday.

The experiment on the effect of light on egg hatching was done by putting eggs in plant culture dishes. The dishes were then placed three times a day in incubators of 16L12D, 12L12D, or 8L16D light conditions. The incubators were all kept at 25C and checked every day.

6. Research on the Effectiveness of Insecticide

TEPP (organnophosphosphates insecticides), pyrethroid insecticides, and neonicotine insecticides were used in these experiments because they are the most widely used insecticides in vineyards. (Table 1)

An experiment of insecticide effectiveness on eggs was done by placing 3 sets of 50 eggs on a plant culture dish sized 100mm in diameter and 40mm tall with filter paper. These eggs were sprayed by the 11 insecticides listed in the table, like Acetamiprid WP. These plant culture dishes were then put in an incubator. The incubators had light conditions of 14L10D and a temperature of 25°C. The amount of hatched eggs were checked at 9:30 AM every day.

1,000-2,000 of Lycorma Delicatula’s imagoes and nymphs were collected in Chungju-Si Yongam-Dong, Seokso-Dong and used in experiments after being placed in

60x60x100cm insect cages for a day. Experiments on the nymphs were done by putting five 4th stage nymphs in a plant culture sized 100mm in diameter and 40mm tall with a grapevine branch, then sprayed with insecticides. Experiments on imagoes were done by putting five imagoes in a culture dish sized 72x72x98mm with a grapevine branch and filter paper, then spraying them with insecticides. The death rate was checked after 2 hours and 24 hours. The experiments on nymphs were repeated four time, and the experiments on imagoes were repeated 5 times.

7. Field experiment

Field experiments were done three times in vineyard in Chungju-Si Yongam-Dong in May and September of 2009. Widely used and cheap insecticides were selected through various tests and used in field experiments. The team also made sure that each insecticide was manufactured by different company. Experiments were repeated 3 times per each insecticides, and there were 3 test sections in the vineyard per insecticide. The experiment was done by checking the population of Lycorma Delicatula per tree before and after spraying the test section with diluted insecticides in the recommended concentration.

IV. Result and Contemplation

1. Population and Damage in Vineyards

(1) Population (P.10-13)

Through July to August in 2008 and 2009, the team traveled through different routes by car in Chung-Buk state. Observed host plants of Ggot-mae-mi like hyun poplar (Populus tomentiglandulosa), grapevine, and tree of heaven to count nymph and imago population. After observing 194 spots in Chung-buk's districts of 9 Si, Gun, 47 Eup, Myeon, Dong till 2008, the team found populations of Lycorma Delicatula in Chungju-Si, Cheongwon-Gun, Jincheon-Gun, Boeun-Gun. (Chart 2) In 2009, the team observed 258 spots in Chung-buk's districts 10 Si, Gun, 66 Eup, Myeon, Dong. After one year, 2009, the area of Lycorma Delicatula's population increased. From 2008 to 2009, Lycorma Delicatula expanded its area of habitation. In 2009, it was observed in Eumseong-Gun, Jeungpyeong-Gun, Goesan-Gun, Okcheon-Gun, and Chungju-Si, areas where it had previously not been seen. (Table2)

In 2009, the team couldn't observe Lycorma Delicatula in the Yeongdong area, which is near the Chung-buk area. However considering the spreading rate of Lycorma Delicatula, the outbreak of Lycorma Delicatula in that area is likely.

By observing the area populated by Lycorma Delicatula in 2008, and 2009, the team noticed that during the summer time, Lycorma Delicatula was mainly observed in forests or roads around vineyards, but in the fall, they flew into the vineyards (Table3). In 2008, May to July, Lycorma Delicatula was observed in Chungwon-Gun, Munui-Myeon, Goeun-Ri forest. However, in October, Lycorma Delicatula was observed in vineyards in Chungwon-Gun, Munui-Myeon, and Guryong-Ri. In October the population of Lycorma Delicatula was higher in vineyards than in nearby forests (Table 3). Same phenomenon was observed in Jincheon-Gun and Okcheon-Gun (Table 3). When nymphs are observed in nearby forests, it seems that imagoes will fly into vineyards to lay eggs. Because Lycorma Delicatula completes one life cycle during a year, the amount of chemical control for Lycorma Delicatula in vineyards can be reduced by chemically controlling the nymphs in the area around the vineyard. This phenomenon was observed in area that Lycorma Delicatula was spreading but there weren't Lycorma Delicatula's eggs in the vineyard. However, this does not protect against nymphs in the future, as imagoes will still fly into the vineyard and lay eggs, even when nymphs are chemically controlled in the vineyard. Therefore, a physical barrier to keep imagoes from flying into vineyard is also required.

(2) Damage from Lycorma Delicatula in the Vineyard (P.14-18)

In order to check the symptoms of the damage caused by Lycorma Delicatula, the team observed traditional vineyards and organic vineyards from 2007 to 2009 during the harvest season (August to September). Damage caused by Lycorma Delicatula was observed in leaves, branches, and fruits. The most dominant damage was caused by sooty mold disease, which is caused by the honeydew secreted by Lycorma Delicatula, decreasing salability of fruit. After honeydew was dropped on a leaf, the leaf caught sooty mold disease and turned yellow, as it could no longer absorb sunlight. When the disease was severe, the whole leaf turned black. When taking a closer look at the affected leaf, hypha was only attached on the surface of the leaf, and did not go through the leaf. From this, it was found that, sooty mold disease only occured, where honeydew was dropped. Due to sooty mold disease, only 19.2% of grapes were sold as a fresh fruit in organic vineyards. The remaining of 80.8% of grapes were sold as juice after being washed (Table 4). In traditional vineyards, 79.1% of grapes were sold as fresh fruit, but even those vineyards suffered damages from sooty mold disease because farmers did not use insecticide during harvest season. When there were covers on the grapes, both traditional vineyards and organic vineyards had higher salability as fresh fruit because it kept honeydew from directly touching the fruit. However, it caused secondary financial damage, because workers had to cover grapes and later remove the covers spoiled by honeydew before wrapping the grapes for sale, increasing labor.

In order to observe the damage that came from Lycorma Delicatula sucking on grapevines, the team used cutting slips because it is hard to observe stunted growth in actual vineyards, because grapevines are usually trimmed at 2 years old.

After growing growing grapevines from cutting slips, the team measured the length of internode, thickness of internode, the length and width of the third node's leaf, and put some grapevines in a case with Lycorma Delicatula, while keeping other free of the insect. In the case with insects, nymphs were placed for 10 days, then after 40 days, imagoes were placed for 10 days. The growths of the separate grapevines were observed and compared. In the overall height of growth, grapevines with no Lycorma Delicatula was 81%, grapevines with 3 Lycorma Delicatula was 17%, and grapevines with 5 Lycorma Delicatula was 14% (Picture 2-a). In the growth of stem length of 3rd node, grapevines with no Lycorma Delicatula was 20%, grapevines with 3 Lycorma Delicatula was 14%, and grapevines with 5 Lycorma Delicatula was 9% (Picture 2-b). The growth of stem thickness of the 3rd node was 17% in grapevines with no Lycorma Delicatula, 16% in grapevines with 3 Lycorma Delicatula and 11% in grapevines with 5 Lycorma Delicatula (Picture 2-c). The width growth of a leaf in the 3rd node was 18% in grapevines with no Lycorma Delicatula, 5% in grapevines with 3 Lycorma Delicatula and 3% in grapevines with 5 Lycorma Delicatula (Picture 2-d).

The length growth of a leaf in the 3rd node was 15% in grapevines with no Lycorma Delicatula, 4% in grapevines with 3 Lycorma Delicatula and 1% in grapevines with 5 Lycorma Delicatula (Picture 2-e). These results show that Lycorma Delicatula's sucking causes direct damage to the growth of a grapevine.

Until now, there were only hypotheses that Lycorma Delicatula weakens the defense system of a grapevine. However, through this research, it was observed that Lycorma Delicatula stunts the growth of grapevines not only by directly sucking the sap, but also by leaving a hole from which the sap leaks. Even though further research is required, it is hypothesized that the hole that Lycorma Delicatula leaves can be a path for pathogenic bacterium to enter the plant's system.

2. The ecology of Lycorma Delicatula in the Vineyard

(1) The Life cycle of Lycorma Delicatula in the Vineyard (P.19-20)

In order to research the life cycle of Lycorma Delicatula, the team collected Lycorma Delicatula's eggs from Chungju-Si Yongam-Dong and observed it in a quarantine. The life cycle of Lycorma Delicatula in a vineyard was similar to the one that is generally reported. The imagoe starts to emerge during July. In the beginning, the abdomen is dark and small, however as it gets older its abdomen start to become yellow and bigger. One female and one male mate during September to October. The female lays eggs in various places like grapevine branches, concrete support fixtures, irrigation water tanks, and house pipes. Lycorma Delicatula lays eggs in these places to keep the eggs from freezing. Lycorma Delicatula completes one life cycle in a year. Lycorma Delicatula's life cycle in quarantine is shown in the picture 3. The 1st stage nymph emerges in the middle of April. Imagoes emerge from beginning of the July to beginning of the November. There was lots of time where the different stages of nymphs coexisted. It is hypothesized the lighting and temperature is responsible for how long it takes first stage nymphs to hatch, therefore the team did additional research on the effect of lighting and temperature on hatching.

(2) Number of eggs per egg sac (P.21)

In order to research the number of eggs per egg sac in egg sacs found in vineyards, the team collected and researched 90 egg sacs. The average number of eggs per egg sac was 32.7±6.49 (Table 5). The average number of eggs per egg sac from Pinus strobus, Acer palmatum, Styrax japonica, and Chaenomeles sinensis were also similar. After 2 years of observation, the team found that Lycorma Delicatula only lays eggs once of a year. There were 30-50 eggs in a female's abdomen when it was opened before laying eggs. Further study on the amount of eggs laid and the reproductive rate of Lycorma Delicatula is required because the amount of eggs observed in this research differed from previous studies.

(3) Effect of temperature and light on hatching of egg (P.22-27)

Since Lycorma Delicatula's eggs are observed between October and May, the team placed collected eggs in temperature between 10°C and 30°C and checked the hatching rate in order to find the ideal temperature for eggs to hatch. The hatching rate was 27% in 25°C, 16% in 20°C, and 14% in 15°C (Picture 4). In 25°C, eggs started to hatch from the 10th day until the 17th day. As the temperature decreased, the time it took for eggs to hatch increased. In temperatures of 20°C, eggs started to hatch after the 16th day. At 15°C, eggs started to hatch from the 26th day. At 30°C, eggs started to hatch from the 10th day. However the hatching rate was significantly lower after the 10th day compared to 25°C. At 10°C, none of the eggs hatched. The time it took for eggs to hatch decreased as the temperature increased, and no eggs hatched at 10°C.

After making a non-linear growth model of Lycorma Delicatula, it was observed that the growth rate of Lycorma Delicatula was slowed down at higher temperatures. According to the linear growth model, the calculated developmental zero point was 12.75°C. The developmental zero point of the Comstock mealybug (Pseudococcus comstocki) is 11.9°C. However the developmental zero point used in this research was just a calculated point - not a point where actual biological growth stops (Jeon, 1996).

According to the overall research, 25°C was considered the most ideal temperature for the hatching rate, and this result complies with observation of Lycorma Delicatula where 1st stage nymphs emerges from middle of April (Picture 3) and can't be observed after June, at similar temperature to the 25°C.

As recent winters were warmer, it was possible for Lycorma Delicatula nymphs to emerge earlier.From this, it is possible to conclude that temperature is the best predictor for the hatching time of Lycorma Delicatula, as its hatching is temperature dependent.

After previous experiments proved that the temperature was the critical condition that affected the hatching of the Lycorma Delicatula egg, the team researched the effect of different light conditions on the hatching of the eggs. In long light (16L8D) the hatching rate was 28.7%. In middle light (12L12D) the hatching rate was 28%. In short light (8L16D), the hatching rate was 34.7%. Overall they were all similar and the team couldn’t find any significant characteristic in a linear growth model (Table 7). Therefore, the light condition was not considered a factor that affected the hatching rate of Lycorma Delicatula. It is also better to predict emerging date by change of temperature rather than a lighting condition.

Research was done on the effect of cold treatment of varying duration on the hatching rate of Lycorma Delicatula eggs. The goal was to find out which temperatures Lycorma Delicatula can survive, and whether they need breaking dormancy period (time to get out of hibernation status).

(Table 5). None of the eggs hatched in an incubator with a temperature of 25°C and light condition of 14L10D after a cold treatment in -10°C for 5-20days. Only 14% of eggs hatched after 5 days of cold treatment at 0°C, after which they were moved to 25°C incubator. This was 50% lower than the hatching rate of eggs without cold treatment. When there was 10-20 days of cold treatment in 0°C, the hatching rate was 5.0 - 8.7%. After 10 days of cold treatment at 5ºC, the hatching rate was 10%. After 15 days of cold treatment at 5ºC, the hatching rate dropped down to 4%. However it increased to 24% at 20 days of cold treatment at 5°C, which was similar to the hatching rate without cold treatment. This phenomenon seemed to happen because it took time for low temperature-resistance material to become active. When a 20°C, 14L10D incubator was used, the hatching rate decreased compared to the 25°C incubator (Table 5). When there was 5 days of cold treatment at -10°C, the hatching rate was 1.3%. When there was more than 5 days of cold treatment at -10°C, hatching rate dropped to 0%. When there was 0-20 days of cold treatment in 0°C and 5°C, the hatching rate was 10%. The hatching rate decreased as cold treatment increased. When there was no cold treatment, the hatching rate of an incubator with 15°C 14L10D conditions was 14%, and the hatching rate of an incubator with 20°C 14L10D condition was 16% (Table 5). When eggs were placed in an incubator with 25°C 14L10D condition after 5 - 20 days of cold treatment in -10°C, none of the eggs survived. There wasn't much difference in the hatching rate of an incubator at 15°C depending on time of cold treatment from 0 days to 20 days when cold treatment was done in 0°C and 5°C. When a 30°C 14L10D incubator was used, the overall hatching rate decreased (Table 5). Lycorma Delictula went into dormancy when was a low temperature and cold treatment isn't necessary for it's hatching.

3.Effect of Control

Chemical control experiments were done on eggs, nymphs and imagoes using insecticides used on vineyards in order to find the most effective method of control.

(1) Effect of insecticide based on the developmental stage of Lycorma Delicatula (P.28-30)

Lycorma Delicatula eggs were placed in 25°C conditions after being sprayed with insecticides that were widely used in vineyards. 18.7% - 26.7% of eggs hatched after 22 days. This rate was similar to the hatching rate when there were no insecticides used. Therefore, there weren't any effective insecticides used widely in vineyards that could kill the eggs (Table 8). Since these experiments were done directly on the eggs, it would be even harder to expect any real effect from insecticides used in vineyards, when there is a natural coating on eggs. For these reason, it is almost impossible to use any widely used insecticide to kill eggs between October and April, since the eggs are hibernating in coating. The most realistic way to kill eggs during the winter is by physically crushing eggs.

When the same insecticides were used on Lycorma Delicatula imagoes, all of the insecticides had an 100% death rate after 24 hours at the recommended diluted concentration, again, with the exception of Bifenazate SC (Table 8). When Dr. Park did a chemical control experiment on Lycorma Delicatula's nymphs on trees of heaven, Chloronicotinyls and Organophosphosphates insecticides were effective. When oil based Deltamethrin, liquid based Imidacloprid, flowable

Clothianidin, and oil based Fenitrothion were used, the death rate was 100% after 24 hours (Park, 2008).

(2) Effect of control experiment (P.31-32)

Field experiments were done in order to see if selected insecticides actually worked in the field. The team used a closed vineyard in Chungju-Si Yongam-dong that had 5 year old camberley grapevines. There weren't any other insecticides used before and after experiment. Insecticides were sprayed in 2009, at the middle and end of May and September, after checking the population of Lycorma Delicatula. The survival rate of Lycorma Delicatula was checked after the 3rd, 5th, and 7th day after spraying. When insecticides were sprayed during middle of May, the death rate was 90%. However, the death rate dropped by 10% for the Lycorma Delicatula insects born after the initial spraying (Picture 6-A). When insecticides were sprayed at the end of May, when most of hatching was done, the death rate of all 4 insecticides were over 90% (Picture-B). When insecticides were used in September, when imagoes emerge after harvest, all of the 4 insecticides' death rate was over 90% (Picture 6-C). Insecticides were only effective on nymphs and imagoes, not on eggs. From this, it is evident that additional spraying is required when there is an influx, or when there are newly hatched insects, because insecticides are only effective when the insects are directly exposed to them. Research on the effective time of chemical control and more environmental friendly ways of control is required. Dryinus browni Ashmead, 1905 was reported as natural enemy of Lycorma Delicatula (Mita, 2009). Further research is needed on how to use this natural enemy as a control method.

V. Summary (P.33-34)

In order to provide basic information to control Lycorma Delicatula, the team researched damage caused by Lycorma Delicatula, its ecology, and methods for controlling it in vineyards.

1. Lycorma Delicatula was observed at Chungju-Si, Cheongwon-Gun, Jincheon-Gun, Boeun-Gun in 2008 and it was additionally observed in Eumseong-Gun, Jeungpyeong-Gun, Goesan-Gun, Okcheon-Gun, and Chungju-Si in 2009.
2. Lycorma Delicatula caused sooty mold disease and decreased the photosynthesis activity of plants, as well as weakening the defense system of plants by sucking on grapevine branches.
3. When there was no cover on grapes, the salability in organic vineyard was 19.2% while it was over 98% when there was cover.
4. Lycorma Delicatula caused serious damage by sucking sap from grapevines. When there was no Lycorma Delicatula, grapevines grew 81%. When there was 3 Lycorma Delicatula, grapevine grew 19.2%. When there were 5 Lycorma Delicatula, grapevine grew 14% in total height.
5. There were 32.7±6.49 eggs on average per egg sac.
6. The hatching of Lycorma Delicatula depended on temperature rather than lighting.
7. The best temperature for Lycorma Delicatula to hatch was 25°C and took 12.7±2.60 days to hatch.

8. The zero developmental point of Lycorma Delicatula was 12.75°C according to a linear growth model made by graphing temperature and growth rate.
9. Experiments were conducted with 11 insecticides on eggs, nymphs, and imagoes. None worked on eggs, while 10 worked on nymphs and imagoes.
10. 4 types of insecticides were effective in a field experiment.