Correlation between Virus Attacks at The Several Phases of Growth with The Yield of Chili Pepper (*Capsicum annuum* L.) in Lowland

Elly Kesumawati¹, Sabaruddin¹, Muhammad Asdhani¹ and Sofyan ²

¹ Department of Agriculture, Faculty of Agriculture, Syiah Kuala University, Jalan Tgk Krueng Kalee, Darussalam Banda Aceh23111, Indonesia
² Social Economic Department, Faculty of Agriculture, Syiah Kuala University, Jalan Tgk Krueng Kalee, Darussalam Banda Aceh23111, Indonesia

*Corresponding Author: ellykesumawati@unsyiah.ac.id*

Abstract

Chili pepper are very important spices and a source of cash income for small crop vegetable farmers in Indonesia. Viruses are rapidly becoming one of the most serious plant pathogens in tropical, subtropical and temperate regions, affecting increasing number of crops with a disastrous impact on productivity. The correlation between the virus attacks at the several phases of growth is assumed to be caused of decreasing yield of chili pepper in lowland. This research aims to determine the effect of virus attacks on various phases of growth and the yield of chile pepper in lowland. The research was conducted at the Lambeugak Village, Aceh Besar. The sampling was randomly selected from virus symptomatic and non-symptomatic plants. In the present study, approximately 5048 chili pepper plants were cultivated at a field of Aceh Besar, and viral symptom survey, diagnosis of infecting viruses, and fruit yield survey were conducted. The result showed that at 15 days post transplanting (dpt) the percentage of infected plants with begomoviral symptom is 3,1%, its increasing to be 65,1% at 30 dpt, and becoming 89,9% at 45 dpt. At 60 dpt, all the plants showed begomoviral symptom. Moreover, the virus infection result in a general decrease in the plants growth and reduced yields. In the early virus symptomatic plants (30 dpt) had significant reduction of total fruit compared to late virus symptomatic plants (60 dpt). The correlation between virus infection day and the growth of the plant has been observed from plant height, stem diameter, number of fruit per plant, weight of fruits per plants and the length of fruits. The highest correlation value of 0,99 obtained on plant height, stem diameter, number of fruit, and fruit weight and length.

Keywords: chile pepper, growth, lowland, virus, yield

1. Introduction

Chili pepper (*Capsicum annuum* L.) is one of the important horticultural commodities in Indonesia. This plant cultivated because of its high economic value, and a source of cash income for small crop vegetable farmers in Indonesia with production occupying at least 155,000 ha and involving > 500,000 farmers (Vos and Duriat 1995; Mustafa et al., 2006).
The production of chili pepper in Indonesia is still very low, many factors that influence it, and one of them is viral attacks (Subekti et al., 2006). In 1999, Pepper Yellow Leaf Curl Disease (PepYLCD) caused by geminiviruses was first observed in West Java (Sulandari et al., 2001, 2006; Sumardiyono et al., 2003) and annual crop census data for the period from 2000 to 2006 showed the outbreak of this disease (De Barro et al., 2008). Prior to this, PepYLCD had never been observed in chili from Indonesia (Vos, 1994).

The Geminiviridae family encompasses a large number of plant viruses with circular and single-strand DNA genomes. On the basis of their genome organization and biological properties, geminiviruses are divided into the following nine genera: Begomovirus, Becurtovirus, Capulavirus, Curtovirus, Eragrovirus, Grablovirus, Mastrevirus, Topocuvirus, and Turncurtovirus (Saunders et al., 2000).

Over the past three decades, diseases caused by begomoviruses have contributed to production losses in solanaceous crops, particularly tomatoes (Solanum lycopersicum L.), peppers (Capsicum spp.), and eggplants (Solanum melongena L.), in many tropical and subtropical regions of the world (Kenyon et al., 2014). Whitefly, Bemisia tabaci (Gennadius), is the natural vector of begomoviruses (Cohen and Harpaz, 1964).

Viruses that naturally cause disease in chili plants have about 30 more viruses (Green and Kim, 1991), including the Chile Vein Mottle Virus (ChiVMV), Cucumber Mosaic Virus (CMV), and Tobacco Mosaic Virus (TMV). ChiVMV, CMV, and TMV are the main viruses that attack chili plants in Indonesia (Wardanah, 2007). Sari et al. (1997) stated that the CMV viruses is able to decrease number and weight of fruit per plant by 81.4%.

Koeda et al. (2016) reported that from five local farmers’ fields located at the suburbs of Banda Aceh which each field approximately 500 to 3,000 plants of C. annuum were cultivated. The yellow leaf curl symptoms were observed in more than 81% of plants in all the fields, and symptoms reached 100% at four fields out of five.

The viruses that can cause 40% to 100% yield loss depending on the age of attacks, host and virus strain (Sudiono, 2005). According to Vivaldy (2017), viruses in chili pepper occurred since the vegetative growth, the plants become stunted or dwarf. Virus attacks inhibit the vegetative development of plants that can cause losses up to 100%.

The time of virus attack cannot be predicted correctly but the symptoms of attack can be seen from changes in plant morphology. According to Mudmainah and Purwanto (2010), if the virus attack occurs in the generative phase the intensity of the attack is generally lighter compared to the infected plant in the vegetative phase. Chili pepper that growth in the lowlands usually has more problems like-bacteria, fungi, nematodes, and viruses. Therefore, this study aims to determine the correlation of virus attacks in several phases of plant growth and yields of cultivated chili plants in lowland.
2. Materials and Method

Field survey and seedling

Field experiments were conducted from November 2016 to March 2017 in a field at Lambeugak Village, Aceh Besar, Indonesia. The seedling of *C. annuum* was cultivars 'Lado'. The method for seedling was chili pepper seeds soaked in warm water for 12 hours, then seeds were drained and wrapped in a damp cloth for 12 hours, then seeds were sown in small polybags (10cm x 5cm), each polybag contains a mixture of soil and compost in a ratio of 1:1, and 1 chili seed. The seedling were growing under shade conditions, watering was done in the morning and evening, until the plants 30 days old.

Land preparation and transplanting

The tillage was carried out twice, the first tillage was using a tractor and the second tillage with a hoe as forming beds. The size of beds 1.5m x 60m as many as 23 beds. The beds were closed using plastic mulch. The planting hole was made in the mulch with a distance of 40cm x 60cm. Seeds were transferred to the field after 30 days old, which the total chili pepper plants are 5048 plants. Plants were watering in the morning and evening. The NPK fertilizer solution was given in each planting hole at 30 and 60 dpt (NPK 23 kg which has been dissolved in 50 L of water). Pesticides as Pegasus 500 SC (1.5 ml/L) and fungicide Score 250 EC (1.5 ml/L) was given at 15 and 45 days post transplant (dpt).

Determination of samples plants that were infected with a virus

Chili pepper that are infected by viruses have physical symptoms such as leaves having yellow spots and curly leaves. At the beginning of the virus attack, the symptoms caused in the leaves are yellow spots on the veins, curly or curled edges of leaves and new shoot colors for plants that are attacked by dark green viruses. Sampling was carried out using the *Purpose Sampling* method where each sample was chosen randomly, by setting 6 beds as sampling locations, each bed consisted of 10 plants. The selection of sample plants that were virus symptomatic was carried out every 15 days (15, 30, 45, 60 dpt). The plant that was infected with viruses is given a red ribbon and label.

Observation of viral symptomatic chili pepper and fruit productivity

The parameters observed were plant height, stem diameter, number of fruit crops, fruit weight, total fruit weight, potential yield, and the correlation value between the time of the virus attack on crop yields. The data were analyzed using chi square methods (correlation test).

The percentage of virus attacks is calculated using the following formula:

\[
\text{Virus Attacks (\%)} = \frac{\text{number of symptomatic plant}}{\text{number of plant in plot}} \times 100\% 
\]

Calculation of potential results using the following formula:

\[
\text{Potential Yield (ton / ha)} = \frac{\text{Land Area (ha)}}{\text{Spacing (m)}} \times \text{Fruit weight per plant (g)}
\]
For correlation to find the relationship between two or more quantitative variables.

\[ r = \frac{(n\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{(n\Sigma x^2 - (\Sigma x)^2)(n\Sigma y^2 - (\Sigma y)^2)}} \]

Information:
- \( r \) = correlation value
- \( x \) = days of symptoms of virus attacks
- \( y \) = growth and yield of chili pepper plants
- \( n \) = amount of data

3. Results and Discussion

Field survey of viral symptomatic attack chilli pepper

In the present study, approximately 5048 chilli pepper plants that were cultivated at a field of Lambeugak Village, Aceh Besar, Indonesia. None of the seedling had viral symptom at transplanting stage. Typical begomovirus-like symptoms observed on chilli pepper plants in the field including yellowing at 15 dpt, the viral-symptomatic plants were observed 157 plants (3.1%) and the number of non-symptomatic plants were 4882 (Table1). There after, the number of plants with begomovirus-like symptom increased. At 30 dpt viral-symptomatic plants become 3286 plants (65.1 %) and non-symptomatic plants 1762 plants. At the age of 45 dpt, the viral attack was getting worse with 4539 viral-symptomatic plants (89.9 %) and 509 non-symptomatic plants. At the age of 60 dpt, all the plants become the viral-symptomatic plants (100%).

Table 1. Percentage of virus attack on chili pepper at the age of 15, 30, 45, and 60 dpt

<table>
<thead>
<tr>
<th>Days post transplanting</th>
<th>Total plants</th>
<th>Non-symptomatic plants</th>
<th>Viral-symptomatic plants</th>
<th>Percentage attacks (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>5048</td>
<td>4882</td>
<td>157</td>
<td>3.1</td>
</tr>
<tr>
<td>30</td>
<td>5048</td>
<td>1762</td>
<td>3286</td>
<td>65.1</td>
</tr>
<tr>
<td>45</td>
<td>5048</td>
<td>509</td>
<td>4539</td>
<td>89.9</td>
</tr>
<tr>
<td>60</td>
<td>5048</td>
<td>0</td>
<td>5048</td>
<td>100</td>
</tr>
</tbody>
</table>

This result implied that some begomoviruses were associated with severe damage in pepper production at Aceh Besar, Indonesia. The percentage of virus attack increased during the increasing of plants age. This result was similar with Koeda et al., (2016) that mention, yellow leaf curl symptoms, which are typical symptoms of begomoviruses, were observed in most of the pepper plants cultivated at the fields of local farmers in Aceh Besar, DNA-A full-length sequences were determined and clarified that *Pepper yellow leaf curl Indonesia virus* (PepYLCIV), *Tomato yellow leaf curl Kanchanaburi virus* (TYLCKaV), and *Ageratum yellow vein virus* (AYVV) were infecting pepper plants. Kesumawati et al. (not publish, 2018) showed that the number of plants with viral symptom was found at 30 dpt in Saree (Aceh Besar), Indonesia, in the medium land (450 m from sea level) and the number of symptomatic plants increased 100% at 120 dpt (total of 3381 plants). In Lambeugak which sea level 30 m, the virus attack to all of plants more early (60 dpt) compare to Saree. Trisno et al., (2009) reported that the occurrence of yellow leaf curl disease on pepper was reported from almost all pepper growing areas in Indonesia, and disease incident ranging from 37.8 to 97% at West Sumatra.
Moreover, Aidawati et al., (2002) showed that the percentage of virus attacks increased with increasing numbers of vectors. The high percentage of attacks is influenced by the number of populations and the diversity of vectors in the field.

**The comparison of plant height in viral-symptomatic plants and non-symptomatic plants**

In this study, the plant height at 30 dpt of viral-symptomatic plants was 29.68 cm, and non-symptomatic plants 40.06 cm, with a difference of 10.38 cm. At 45 dpt the plant height of viral-symptomatic plants was 44.23 cm, and non-symptomatic plants 60.78 cm, by 16.55 cm difference. At 60 dpt, all plants were viral-symptomatic plants which 66 cm of height. The results showed that the viral-symptomatic plant disturbed the vegetative growth of plants, the leaves become yellowing, plants become stunted or dwarf. The viral-symptomatic plants have a lower height compared to non-symptomatic plants. Latifah (2008) mentions the effect of viruses inoculation on several chili pepper genotypes causing inhibition of plant height from 30.77 % till 65.56 %.

![Figure 1. Comparison on plants height in viral-symptomatic and non-symptomatic chili pepper plants at 30, 45 and 60 dpt](image)

The comparison among the plant height in viral-symptomatic plants

Figure 2 showed, plant height of viral-symptomatic chilli pepper plants at 30, 45 and 60 dpt from the same plants. At 30 dpt, 45 dpt and 60 dpt, the height of each viral-symptomatic plants was 38.04 cm, 48.85 cm, and 66.00 cm. These data showed that the begomovirus attack in the vegetative growth of the plants (30 dpt) were disturbed the plants height and plant growth. Koeda et al. (2016) mention that there is some virus attack to the chilli pepper in Aceh, which virus interactions in those mixed infections could play an important role leading the development of complex diseases, and problem might be more complicated.
The comparison of stem diameter in viral-symptomatic plants and non-symptomatic plants

Figure 3 showed that the stem diameter at 30 dpt of viral-symptomatic plants was 0.40 cm, and non-symptomatic plants 0.48 cm, with a difference of 0.8 cm. At 45 dpt of viral-symptomatic plants was 0.56 cm, and non-symptomatic plants 0.64 cm, by 0.08 cm difference. At 60 dpt, all plants were viral-symptomatic plants which the average diameter of the infected plant was 0.89 cm. There were slightly differences in the stem diameter of viral-symptomatic plants and non-symptomatic plants.

The comparison among the stem diameter in viral-symptomatic plants

Figure 4 showed, the stem diameter of viral-symptomatic chili pepper plants at 30, 45 and 60 dpt from the same plants. At 30 dpt, 45 dpt and 60 dpt, the height of each viral-symptomatic plants was 0.617 cm, 0.752 cm, and 0.857 cm. Plants that are attacked earlier by the virus (30 dpt) have the smallest stem diameter, this proves that earlier virus attacks inhibit plant growth.
Chili pepper fruit yield in viral-symptomatic plants

Fruit yield were collected from 60 samples of viral-symptomatic plants that obtained at 30 dpt, 45 dpt and 60 dpt (Table 2). At 15 dpt there were no-symptomatic plants. Samples showed symptomatic at 30 dpt had 25 chili plants, 45 dpt had 26 plants, and 60 dpt had 9 plants.

Table 2. The chili pepper fruit yield of viral-symptomatic according to the day of virus attacks

<table>
<thead>
<tr>
<th>Parameter of chili pepper</th>
<th>Days of Virus Attacks (dpt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Number of plants (plant)</td>
<td>25</td>
</tr>
<tr>
<td>Plant had fruit (plant)</td>
<td>11</td>
</tr>
<tr>
<td>Plant had no fruit (plant)</td>
<td>14</td>
</tr>
<tr>
<td>Number of fruit per plant (fruit)</td>
<td>3.18</td>
</tr>
<tr>
<td>Total fruit (fruit)</td>
<td>35</td>
</tr>
<tr>
<td>Weight of total fruit (g)</td>
<td>144.5</td>
</tr>
<tr>
<td>Yield (ton/ha)</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Table 2 showed the potential of chili pepper yields for each virus attack day. Plants infected with the virus at the age of 30 dpt have the potential yield of 0.24 ton/ha, at the age of 45 dpt have a potential yield of 0.78 ton/ha, and at the age of 60 dpt has a potential of 1.75 ton/ha. Our previous research also showed that the levels of infection in chili pepper ranged between 80 and 100% in Banda Aceh (Northern Sumatra) (Koeda et al., 2016). Sumardiyono et al. (2003) and Rahayu (2004) noted loses in commercial production ranging from 20 to 100% while yield trials undertaken in 2003 recorded average crop losses in excess of 85%. According to Vivaldy (2017), if the development of the virus in chili plants occurs since vegetative growth will be seen plant growth becomes stunted or stunted. Furthermore, chili plants produce fruit that is slightly small in size and results in not optimal production. Virus attacks inhibit the vegetative development of plants so that they can cause losses of up to 100%.

Figure 4. Comparison on stem diameter of viral-symptomatic plants at 30, 45 and 60 dpt
Correlation between the time of virus attack on the growth and yield of chili plants

The correlation between the time of virus attack and the plant height of chili pepper plants obtained by the value of \( R = 0.992 \) (Figure 5). The days of virus attacks have a very close correlation with the growth and yield of the chili pepper plants (Table 3). If the virus attacks at the vegetative growth the plant will be shorter.

![Figure 5. Correlation of virus attacks time to plant height](image)

According to the Figure 6, the correlation between the time of virus attack with the number of fruits per plant, obtained by the value of \( R = 0.9807 \). So when the virus attacks and the number has a close connection, thus the faster the virus attacks, it is possible that the chili plants will produce less fruit.

![Figure 6. Correlation of virus attacks time to the number of fruits per plant](image)

Table 3. The correlation value between the virus attacks time on the growth and yield of chili pepper

<table>
<thead>
<tr>
<th>Plants parameter</th>
<th>Value of correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>0.998</td>
</tr>
<tr>
<td>Stem diameter</td>
<td>1</td>
</tr>
<tr>
<td>Number of fruits per plant</td>
<td>0.981</td>
</tr>
<tr>
<td>Fruit weight per plant</td>
<td>0.962</td>
</tr>
<tr>
<td>Fruit diameter</td>
<td>0.240</td>
</tr>
<tr>
<td>Fruit length</td>
<td>0.997</td>
</tr>
<tr>
<td>Total fruit amount</td>
<td>0.670</td>
</tr>
<tr>
<td>Total fruit weight</td>
<td>0.669</td>
</tr>
<tr>
<td>Potential results</td>
<td>0.668</td>
</tr>
</tbody>
</table>
Virus in the early stages of plant growth provide serious damage to plants and also have an impact on the yield of chili pepper plants. Kusumawati et al., (2013) reported that the inhibition of plant growth affects the wet and dry weight of plants, the number of fruits and the weight of the fruit. Viral attacks indirectly reduce plant metabolism, reducing the production and quality of plants. Taufik et al., (2007) mention that CMV attacks causes a decrease in the rate of starch accumulation. In the initial phase occurs the accumulation of the starch which is fast and reversed in the final phase of starch accumulation and the ability to synthesize starch also decreases as well as viral attackss causing plants to lose the ability to produce organic acid compounds, sugars, amino acids and proteins, so that growth and plant yields are inhibited. Latifah (2008) states that the disruption of growth and the decline in chili production due to disruption of the plant's metabolic system, through photosynthate utilization produced by plants to be used in the replication and synthesis of virus particles. As a result, plants lack nutrients to be able to carry out vegetative and generative growth.

4. Conclusion

Viral attacks in the vegetative phase (and 30 dpt) inhibited the plant growth, the plants become stunted, had small yellow leaves, plants fail to have fruit because of the absence of flower formation, or fall flowers. The correlations between the day of virus attacked to plant hight and yield has hight with the values of 0.99. Further research needs to be done to looking for geminivirus tolerance by using crossing populaitons in the tolerance varieties of chili pepper plants.

References


