

Begomoviral disease rates and the implications to the growth and yield of chili plants (*Capsicum annuum* L.) at different elevations in Indonesia

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Abstract

The purpose of this study was to determine the effect of the pepper yellow leaf curl disease (PepYLCD) caused by begomovirus at different elevations on the percentage of growth and yield reduction in chili (*Capsicum annuum* L.) plants. The study was conducted in farmer's field at Lambeugak (lowland) with the latitude of 30 meter above sea level (m asl) and Saree (middleland) with the latitude of 485 m asl of Aceh Province, Northern Sumatera, Indonesia. The samples selection was obtained using the *Purpose Sampling* method. Data collection were divided into 2 clusters where the first cluster samples were chosen randomly from 600 plants (300 plants for lowland and 300 plants for middleland) for the disease incident percentage and second cluster samples were chosen randomly from first cluster, each field consisted of 30 plants (15 virus-symptomatic plants and 15 non-virus symptomatic plants) for the reduction of growth and yield percentage. PepYLCD incidence in lowland reached 100 % at 120 day after transplanting (DPT), whereas in middleland it occurred at 150 DPT. At 45 DPT virus-symptomatic plants at lowland encountered higher reduction percentage of growth than the middleland plants, including height of plant (43.6 %) and stem diameter (31.1 %). The yield of virus-symptomatic plants in lowlands encountered higher loss than the middleland plants, including the number of fruits per plant (53.6 %) and productivity (72.6 %). The reduction of growth and yield was also suspected to be the impact of temperature differences that the average and maximum temperatures of lowland (27.68 and 35.53 °C) was higher than the middleland (25.36 and 30.17 °C) during the experimental period. Our present study showed that the escalation of PepYLCD incidence was affected by environmental factors which reduced the growth and yield of chili plants.

Key words: Begomovirus, chili pepper, environment, fruit production, geminivirus

Introduction

Chili (*Capsicum annuum* L.) is one of the most important vegetable commodities in Indonesia due to its high economic value. Chili productivity in Aceh Province in 2016 reached 10.63 ton ha⁻¹ yet in 2017 decreased to 10.31 ton ha⁻¹. But, in 2018 the chili productivity increased to 13.90 ton ha⁻¹ (BPS, 2019). One of the issues for the chili productivity fluctuation is pest and diseases infection which attacks plants from seedling stage to the harvesting stage of plant. The pest and diseases interaction is complex, both in rainy and dry season. Therefore, it causes quite massive loss in chili (Duriat and Sastrosiswojo, 2009).

Common disease which often causes loss in chili cultivation is pepper yellow leaf curl disease (PepYLCD), caused by begomovirus. Begomovirus is transmitted by insect vector whitefly (*Bemisia tabaci* Genn.). It has more than one host plant including staple and horticulture crops (Sulandari, 2004). One of the most common chili infecting begomovirus in Indonesia is bipartite Pepper yellow leaf curl Indonesia virus (PepYLCIV) and another bipartite begomovirus Tomato yellow leaf curl Kanchanaburi virus (TYLCKaV) and monopartite begomovirus Ageratum yellow vein virus (AYVV) are frequently mix-infecting to chili (Koeda *et al.*, 2016). More recently, bipartite begomovirus Pepper yellow leaf curl Aceh virus (PepYLCAV) was isolated from chili plant with PepYLCD (Kesumawati *et al.*, 2019).

Koeda *et al.* (2016) found that the disease has caused serious issues on chili production. From five chili cultivated field around Banda Aceh town, 500-3000 plants showed the virus-symptomatic appearance and positively Begomovirus infected, more than 81 % of the plants were showing yellow leaf curl symptom. From four out of five field had 100 % virus symptomatic plants.

The use of unsuitable variety record reduction in chili productivity frequently being susceptible for pest and disease infection. Therefore, the quality of the seeds is one of determining factors in chili production (Syukur *et al.* 2010). One suitable way to maintain productivity due to viral disease infection on chili is by using superior local variety. According to Ferayanti (2016), Odeng is considered as superior local variety with high production and it is suitable for lowland, middleland and highland reaching 1200 m asl.

In accordance with the effort of reducing viral disease percentage in chili plant, it is important to understand the effect of elevation, either in lowland and middleland, on the rate of viral disease infection, yield and growth in chili plant. The agroecosystem of vegetable is classified into lowland (<350 m asl), middleland (300-700 m asl) and highland (>700 m asl). This classification was arranged in accordance to the optimum needs of temperature for each kind of plant (Djaenudin *et al.* 2002). Budi *et al.* (2013) stated, in middleland, among suitable plant to be cultivated, chili

is one of the crop and the higher growth and yield in middleland could be achieved if the pest and diseases does not exist to cause any harvesting loss.

Based on the above facts, it is pertinent to analyze the detailed data and understand whether the viral disease symptomatic condition could affect the growth and yield of chili in lowland and middleland and the comparison of both elevations.

Materials and methods

Place of research and plant material: The study was conducted in farmer's field at Lambeugak (lowland), Kuta Cot Glie subdistrict, Aceh Besar district with the latitude of 30 m asl, and Balai Pelatihan Pegawai Pertanian (BLPP) field at Saree (middleland), Lembah Seulawah subdistrict, Aceh Besar district with the latitude of 458 m asl, Aceh province, Northern Sumatra, Indonesia. The lowland cultivation started from February until June 2018, while the middleland cultivation started from December 2017 until April 2018. Both of these fields were selected due to the viral disease history of the land in the last three years.

Odeng, a local variety from Aceh, was used for the cultivation. Total number of seeds used were 1 sachet (contained 10 g, 1500 seeds). The seeds were treated with disinfectant before sowing and transplantation was conducted at 30 days after sowing (DAS). At lowland, chili seeds were sown in the tray filled with 5:4:1 refined soil, manure fertilizer, and husk ash for 14 days and after that it were transferred into the 3 cm diameter polybags then, after 30 days seedlings were transplanted to the field. At middleland, chili seeds were sown directly onto the beds, the soil was tilled and manure fertilizer was given for each bed. After sowing the seeds, beds were watered and covered by transparent plastic for 7 days. Then, the cover was changed to the paranet for 30 days till the seedling were ready to be transplanted to the field.

Cultivation: Seedlings were transplanted in the plot (50 x 1 m) with the distance of each plant 50 x 60 cm. Drainage drain was dug 30 cm depth. The fertilization was done by applying 100 kg manure fertilizer for each plot during the land tillage. NPK, KNO₃, and liquid organic fertilizers 3:1:1 (3 kg:1L:1L) was diluted to be stock solution in 50 L water. Each liter of the stock solution was then diluted again to 14L water. The application was done every 7 days (7, 14, 21, 28, 35, 42, 49, 56 and 63 days post transplanting [DPT]) by the dosage of 45 mL for each plant. The watering was done each afternoon. The pest and diseases management was done by applying chemical pesticides.

Samples selection and data collection: The samples selection was based on the *Purposive Sampling* method. The data collection was divided into 2 clusters. First cluster consisted of 300 plants in each location for viral disease incidence analysis. The data were collected at every 15 day interval (15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 DPT). The second cluster consisted of 15 virus-symptomatic plants and 15 non-symptomatic plants on each location for growth and yield data analysis. The growth variables included plant height (cm) and stem diameter (cm) that were observed at 45 and 60 DPT, whereas the yield variables included fruit weight per plant (g) and total productivity based on 10 harvests at 5 days interval, starting from 85 to 130 DPT in lowland and 90 to 135 DPT in middleland.

Daily temperature recording: Air temperature was recorded each hour everyday starting from 30 DPT until the end of research by using Datalogger T&D Thermo 71-wf. Daily temperatures data was downloaded using T&D Thermo Application on Android based device.

Data Analysis

Disease incidence: Disease incidence was obtained by using the equation below:

$$DI = \frac{n}{N} \times 100$$

where,

DI : Disease incidence

n : Number of virus-symptomatic plants

N : Number of surveyed plants

Reduction of growth and yield percentage: Quantitative data of chili plant growth and yield from 15 virus-symptomatic plants and 15 non-symptomatic plants were used in following equation:

$$\text{Reduction percentage} = \frac{(N-S)}{N} \times 100$$

where,

Reduction percentage (plant height, stem diameter and number of fruits per plant)

N : Number of non-symptomatic plants

S : Number of virus-symptomatic plants

Percentage of reduction was analyzed using Independent T-test ($\alpha = 0.05$). It was used to compare the result of different elevation fields.

Results and discussion

Viral disease incidence in chili plants: The study showed that the disease incidence reached 100 % at 120 DPT at lowland, while at 150 DPT at middleland. At the 30 DPT, only 6 plants were found to be virus-symptomatic out of 300 plant. The remaining 294 plants were not showing any virus symptom. Whereas, at middleland, 4 plants were found to be virus-symptomatic (Fig. 1).

At 30 DPT, 2 % viral disease incidence occurred in lowland (Fig. 1). The percentage kept higher in lowland compared to middleland from 30 DPT until 150 DPT. The disease incidence reached 100 % at 120 DPT, which was earlier than 150 DPT of middleland.

In accordance with environment condition such as temperature, viral disease incidence in lowland will increase sharply compared to the middleland or highland due to the relatively higher air temperature, thus, the virus transmitting insect vector actively reproduced themselves and foraged. As a result, chili plants were continued being infected as long as vector kept foraging on the host plants (Sastry and Zitter, 2014). Rathnamma and Patil (2018) stated that the difference of disease incidence and disease severity in certain areas is suspected because of various inoculum source, vector population, and climate condition. In accordance with climate condition, temperature holds important role in deployment dynamics and vector activity as the virus transmission agent. Temperature range between 20-30 °C considered as suitable condition for the vector to reproduce and survive (Cock, 1986). Besides, climate change also influence virus spread in certain area that previously has no history for virus infection and the vector (Rojas *et al.* 2018).

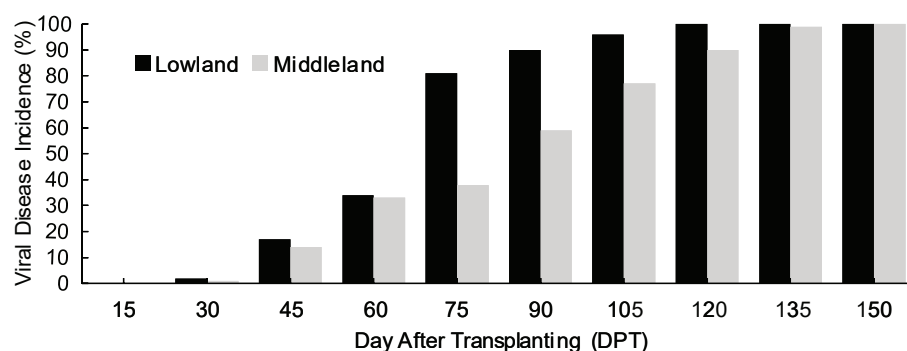


Fig. 1. Viral disease incidence percentage on cultivated chili plants in lowland and middleland

Morales and Jones (2004) reported temperature as the main environmental factor influencing the population dynamic of the *Bemisia tabaci* as vector. In tropical area, optimum condition for *B. tabaci* is 28 °C, with the minimum-maximum point range between 15-33 °C. Furthermore, Singh and Butter (1984) also stated that the *B. tabaci* population drastically influenced by the climate condition that consists of extreme temperature, low relative humidity (below 60 %), and continuously high rainfall intensity that made *B. tabaci* less-adapted to the elevation above 1000 m asl (Morales and Jones, 2004).

According to Fig. 2, average temperatures and maximum temperatures of each 15 days during the cultivation started on 31 to 150 DPT shows the difference, where the average temperature of lowland is 27.68 and 25.36 °C in middleland. While, the maximum temperature in lowland is 35.53 and 30.17 °C in middleland.

Temperature seems to be one of the influencing factors during the cultivation that caused the increased viral incidence. The viral disease development is influenced by the pathogen existence (virus), susceptible host, and conducive environment for pathogen for their multiplication inside plant (Sastry and Zitter, 2014). Some viruses might adapt in high temperature and some might adapt in lower temperature (Jones dan Barbetti, 2012). Legg *et al.* (2011) showed that the infecting virus in both lowland and middleland could invade the host, but in lowland, the virus invades faster than in middleland especially in tropical area.

Growth reduction percentage

Plant height reduction percentage: Average plant height reduction percentage due to viral disease at 45 DPT in lowland was 43.6 % which was significantly different with the middleland (30.0 %). At 60 DPT, the percentage was higher in lowland (42.7

%) and become significantly different with middleland (27.8 %) (Table 2).

Table 2. Average reduction of plant height in chili plants at 45 DPT and 60 DPT in low land and middle land

Plant height	Lowland	Middleland	T _{count}	T _{0.05}
45 DPT	43.6 % b	30.0 % a	2.4	2.1
60 DPT	42.7 % b	27.8 % a	2.7	2.1

Note: Values followed by same letters in each row indicates the mean is significantly not different based on 't' test.

The reduction of plant height was correlated to the viral disease severity. Plant height could be reduced due to the reduction in chlorophyll inside the plant cells which has particular role in metabolism of leaves and other organs. This reduction generally caused by the reduction of leaf size, internode length and number of leaves (Hull, 2002). Kesumawati *et al.* (2018) showed that viral disease interferes vegetative growth, causing the yellowing curly leaves, stunting, and reduced plant height, all of which could be distinguished from virus-symptomatic plant and non-virus symptomatic plants.

Environment conditions, specifically the temperature, in lowland and middleland are known to be affecting the plant height. Higher temperature in lowland would be affecting the transpiration activity. The rise of the temperature in lowland could also affect the vapour pressure in leaf which influence the microclimate of the plant which at the end increases the rate of transpiration. If the transpiration rate increases continuously for certain period, rate of photosynthesis will decrease and eventually cause the lack of metabolism process both vegetatively and generatively (Bhatla and Lal, 2018).

Stem diameter reduction percentage: Average stem diameter reduction percentage due to viral disease at 45 DPT in lowland

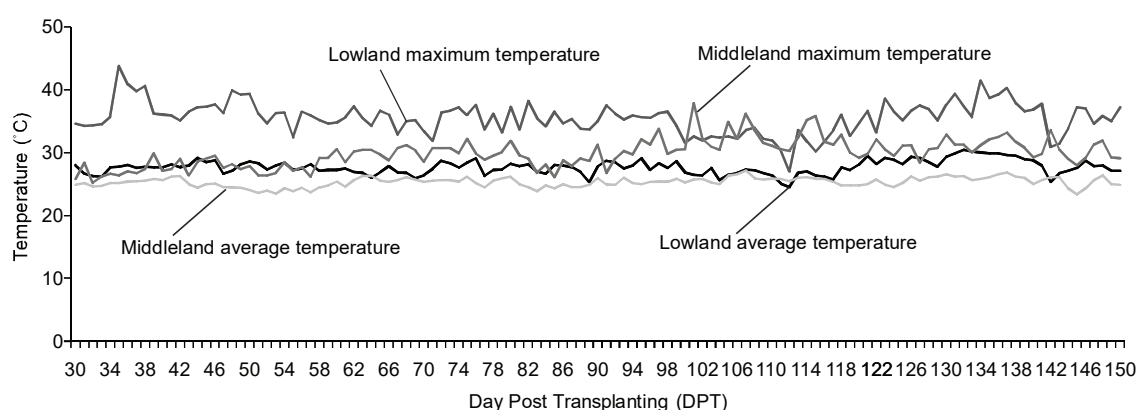


Fig. 2. Average temperatures and maximum temperatures of each 15 days in lowland and middleland

was 26.0 % which was significantly different with the middleland (2.1 %). At 60 DPT, the percentage was higher in lowland (29.8 %) was at par with middleland (24.3 %) (Table 3).

Table 3. Average reduction of stem diameter on chili plants at 45 DPT and 60 DPT in lowland and middleland

Stem diameter	Lowland	Middleland	t _{count}	t _{0.05}
45 DPT	26.0 % b	2.1 % a	3.7	2.1
60 DPT	29.8 % a	24.3 % a	0.6	2.1

Note: Values followed by same letters in each row indicates the mean is significantly not different based on 't' test.

Plants in lowland had less stem diameter as compared to plants in middleland. This stem diameter reduction might be due to the fact that metabolism activity which plays role in stem diameter enlargement might have obstructed because the virus infected plant cells of the lateral meristem that controls the enlargement of stem diameter (Hull, 2002). Just (2017) also stated that Tomato yellow leaf curl virus (TYLCV) is one of begomovirus that inhabit the phloem and cause the limits of shoot tips, leaves, stems, and flowering tissue growth.

Yield reduction percentage

Productivity and fruit number reduction percentage: Average productivity reduction percentage due to viral disease in lowland was 72.6 % which was significantly not different from the middleland. Reduction in fruit numbers in lowland was 53.6 % which was at par with the middleland (Table 4).

Tabel 4. Average reduction of productivity and fruit numbers on chili plants in lowland and middleland

Yield parameter	Lowland	Middleland	T _{count}	T _{0.05}
Productivity	72.6 % a	65.2 % a	1.1	2.1
Fruit Numbers	53.6 % a	47.7 % a	0.5	2.1

Note: Values followed by same letters in each row indicates the mean is significantly not different based on 't' test.

The reduction of fruit weight and numbers caused by viral disease infection tend to be higher at lowland than at middleland. Just (2017) found that the TYLCV inoculated tomato plants experienced yield reduction on 2-4 weeks after inoculation. Furthermore, Hull (2002) stated that the yield reduction in chili plants was due to viral disease infection generally caused by the reduction in size and fruit numbers.

Latifa (2008) also showed that some genotypes of chili when inoculated with virus experienced fruit weight retardation from 31.8 - 99.6 % where the yield loss resulted due to the flower formation failure. Sazali and Ali (2017) also clarified that when virus infect the plants, it is able to hamper the photosynthesis process due to the chlorophyll content reduction and damaged stomata, influencing the quantity and quality of fruit. Moreover, Pramarta (2014) concluded that viral disease infected chili plants exhibited decreased growth and yield both in terms of quantity and quality.

Viral disease incidence percentage in lowland reached 100 % earlier than the middleland. which indicate the temperature is the main factor influencing disease incidence as average temperature in lowland was higher than middleland.

Viral disease significantly affected plant height and stem diameter in lowland than the middleland. As a result, higher yield loss occurred in lowland than the middleland.

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