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Effect of Extreme Rainfall Pattern on The Growth and Yield of Chili Peppers

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ABSTRACT

The purpose of this study was to observe the effect of extreme rainfall patterns in the DI Yogyakarta region on the growths of chili peppers of "rawit" (Capsicum frutescens L.*) and curly pepper (Capsicum annum). The experimental design used was RCBD (Randomized Complete Block Design) with single factor consisting of three levels namely: maximum frequency index (P1), rainfall intensity index (P2), and control treatment (K). The frequency and intensity indexes (P1 and P2) of May-June-July from each weather station were used as the bases of rainfall simulations applied in watering the rawit and keriting chili pepper cultivations. Whilst, control (K) was the watering on the basis of optimum crop water requirement. The growth parameters observed included plant height, number of leaves, age of flowering, age of fruiting, age of first harvest, final weight of biomass, and yield. The data sets were analyzed by using one-way Analysis of Variance (ANOVA) at α=0.05 for each species. The results showed that the three levels of treatments did not significantly affect the growth and yield based on all parameters observed for both of the two species. So even the potted media were flooded, the water easily drained through the holed base of pots, making plant growth undisturbed. This finding suggested that planting chili peppers in pots or elevated media could mitigate the effect of extreme rainfalls.*

1. INTRODUCTION

Climate change is a global event that we feel today where the pattern and intensity of climate elements has changed. This event can be caused by increased gas emissions that store heat in the Earth's atmosphere, forming a thick blanket. This layer is likened to a greenhouse which causes the reflection of long wave radiation from the earth to be trapped, resulting in an increase in the earth's temperature or commonly known as global warming. This causes climate elements to change slowly and in the long term (Nugroho, 2016).

One indication of climate change is the increasing frequency of extreme events in various regions. Extreme events can be defined as climatic or meteorological phenomena that rarely occur at certain places or times of year such as heat waves, cold waves, heavy rains, droughts, floods, and severe storms (National Academies of Science, Engineering, and Medicine, 2016). According to the IPCC (2012), extreme weather and climate have increased the incidence of disasters over the last 60 years, thus having a negative impact on the economies of developing countries.

One of the most widely observed extreme climate phenomena is extreme rainfall events. Extreme rainfall events are conditions where rainfall exceeds a certain threshold for a certain period of time in one area or in several areas (National Academies of Science, Engineering, and Medicine, 2016). The determination of the threshold of extreme rainfall is different in some areas. According to BMKG (2010), rainfall of more than 100 mm per day can indicate the occurrence of extreme weather.

Extreme rainfall can cause floods and landslides. According to Lassa (2012) there were 3,980 flood events which resulted in damage to crops on an area of 298 ha/event during 1970-2011 in Indonesia. Floods and landslides that occur simultaneously have a wider impact on crop damage, which is as much as 941 ha/event. Flood events can cause damage to plants due to waterlogging in the soil which causes soil pores to be filled with water. As a result, the space for oxygen needed by plant roots in the soil is reduced. Lack of oxygen in the roots can cause root tissue to rot so it can stop plant growth and development (Bekker, 2021). In Siamese citrus, high rainfall throughout the year results in phenological chaos. This chaos occurs due to the increase in the frequency of flowering of Siamese citrus plants in a year but the flowers do not become fruit (Ashari *et al*., 2015).

Extreme rainfall conditions can be observed from changes in the volume of rain which is the accumulation of daily, monthly, and annual rainfall (Nugroho, 2016). The Expert Team on Climate Change Detection and Indices (ETCCDI) also developed 12 extreme rain indices that can describe monthly and yearly extreme rain events. Several studies use this index to see extreme rain events that occur both on a global and regional scale. On a global scale, the extreme rain index shows a trend towards wetter conditions in the 20th century (Alexander *et al*., 2006). On a regional scale, Misnawati & Perdanawati (2019) analyzed trends in the extreme rain index in the Sumatra Island region. The results obtained show a positive trend in the extreme rain index in most of the rain stations spreading across the island of Sumatra.

One of the agricultural commodities whose productivity depends on climatic conditions is chili pepper. In the rainy season, chili production decreases so the price of chili increases. One of the causes of the decrease in chili production during the rainy season is disease. Humid conditions when it rains can increase disease attacks on chili (Meilin, 2014).

Studies on the impact of extreme rainfall on plant production have been carried out (Kong *et al*., 2013). However, a study on the impact of extreme rainfall on the growth of horticultural crops, especially chili, has not been reported. Therefore, this study aims to analyze the trend of the extreme rain index in the DI Yogyakarta region and find out the impact of extreme rain patterns on the growth of cayenne (rawit) and curly (keriting) chili peppers.

2. MATERIALS AND METHODS

2.1. Extreme Rainfall Indices Calculation

The extreme rainfall indices were calculated using the Climpact2 software version 1.2.8 developed by the Expert Team on Climate Changes Detection and Indices (ETCCDI). The indices are calculated from daily rainfall data for the period of 1988-2019 at 14 weather stations spreading across the eastern region of DI Yogyakarta, which can be seen in Figure 1. The rainfall data set used is from the Serayu Opak River Basin Center (BBWSO). Extreme rain index values are calculated in annual and monthly periods. The annual index trend, to determine the significance of the trend, was analyzed using the Mann-Kendall test.

Simulation of extreme rainfall on plant growth was carried out by watering treatment where the amount of treatment given was based on the monthly indices in May – June – July. This time is adopted because it is chili planting season, the transition between the rainy season to the dry season (Dinas Pertanian, DI Yogyakarta, 2009). The extreme rainfall index used is the monthly index value of Rnnmm and RXnnday. The Rnnmm index is an index that expresses the number of days in a month with rainfall of more than nn millimeters. The RXnnday index is an index that expresses the maximum rainfall in nn days during a month. The value of nn on the Rnnmm index has a value of 10-100 with multiples of 10. This is based on the definition of heavy rain according to the BMKG (2010) which is rain with an intensity of more than 50 mm per day. Meanwhile, very heavy rain is rain with an intensity of more than 100 mm per day (Sosrodarsono & Takeda, 1977). In the RXnnday index, the value of nn is based on the value of the monthly Consecutive Wet Days (CWD) index which is the number of consecutive days of rain. Thus, nn has values ranging from 1 to monthly CWD values of 10, 9, and 6, respectively, for May, June, and July. The results of the calculation of the index used as treatment levels can be seen in Table 2.

Table 1. The treatment given to the experiment

Code	Treatment Description
P1	Based on the average maximum value of the Rnnmm indices in May – June – July for 32 years period from 14 rain stations. The value of nn on this index is 10 – 100.
P2	Based on the average maximum value of the Rxnnday indices in May – June – July for 32 years period from 14 rain stations. The number of days nn on this index is based on the maximum value of the monthly CWD index.
K	Based on the value of crop water requirements (CWR) which is calculated from the value of potential evapotranspiration for maize and chili plants in May – June – July.

As a comparison treatment, the plants were given watering based on the Crop Water Requirement as K treatment. The value of CWR was calculated by multiplying potential evapotranspiration (ETo) by plant coefficient (Kc). The ETo value was calculated by the Penman-Monteith equation where the data set used is climate data of Playen, Plunyon, and Barongan stations from 2011-2015. The climate data used include minimum temperature, maximum temperature, humidity, wind speed, and duration of sunlight. Results of CWR calculation are presented in Table 3. The indices and CWR value were converted into the volume of water given to the plant. The conversion is done by multiplying the rainfall indices (mm) by the surface area (mm^2) of a pot with a diameter of 30 cm.

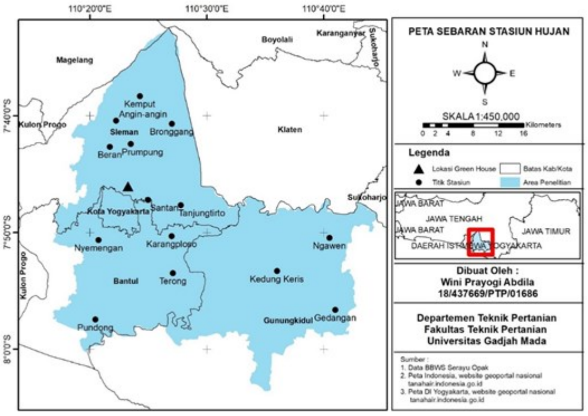


Figure 1. Map of weather station distribution and Greenhouse locations

Table 2. Monthly average maximum index value of 14 weather stations used as treatment

Index	Maximum Value			Index	Maximum Value		
	May	June	July		May	June	July
R10mm	11	8	7	RX1day	87.6	114.24	99.07
R20mm	6	5	4	RX2day	112.59	136	109.55
R30mm	4	4	3	RX3day	138.61	146.51	121.34
R40mm	3	3	2	RX4day	150.76	165.68	127.41
R50mm	2	2	1	RX5day	160.87	176.35	135.19
R60mm	2	2	1	RX6day	178.92	181.23	143.26
R70mm	1	1	1	RX7day	188.26	191.38	151.81
R80mm	1	1	1	RX8day	203.01	200.3	157.49
R90mm	1	1	1	RX9day	209	205	162
R100mm	1	1	0	RX10day	214.57	219.35	170.65

Table 3. The average of CWR value at 3 weather stations

Development Stage	Week After Planting (WAP)	ETo (mm/day)	Kc	CWR = ETo*Kc	Watering Volume (mL/day)
Initial	1	0,14931	0,4	1.178	80
Vegetative	2	0,14931	0,75	2.209	160
Flowering	3 – 4	0,14931	1,1	3.240	230
Fruiting	5 – 9	0,13681	1	2.771	200
Fruit Ripening	10 – 15	0,13819	0,9	2.514	180

2.2. Plant Growth Experiment Procedure

The plant growth experiment was carried out in January-May 2021. The location for observing plant growth was at the Silviculture Greenhouse, Faculty of Forestry, Gadjah Mada University. Two species of chili pepper used are rawit/cayenne (*Capsicum frutescens*) and keriting/curly (*Capsicum annum*) chili whose ages of 3 weeks old. The experimental design used was Randomized Complete Block Design (RCBD). Blocking is done to reduce the influence of environmental conditions, especially sunlight so that it can increase the level of accuracy of the experiment (Nugroho, 2008). Single treatment of watering method based on the simulated rainfall and crop water requirement included three levels namely: maximum frequency index (P1), rainfall intensity index (P2), and optimum crop water requirement as control (K). P1 treatment was based on the Rnnmm index which was watered every 2-3 days. P2 treatment was based on the RXnnday index which was watered every day for nn consecutive days. Meanwhile, K treatment is carried out every day. The treatment was given by sprinkling water using a measuring cup where the volume of each watering was carried out and the watering time was different for each treatment. The treatment was applied when the plants were already 9 days old after transplanting. In this experiment, chili plants were planted in 30liter buckets with holes at the bases. Placement of the bucket is divided into 3 blocks for each species of chili plant where each block has 3 treatment levels. The soil that used for planting medium was taken from Tegaltirto Village, Berbah District, Sleman, Yogyakarta. It has a composition of sand, silt, and clay fractions of 50%, 34% and 16%, respectively, so that it has a clay texture class. Each bucket is filled with soil weighing 20 kg. The treatment was given by sprinkling water using a measuring cup where the volume of each watering was carried out and the watering time was different for each treatment.

2.3. Plant Growth Parameters

Plant growth parameters, including plant height and number of leaves were taken once in 7 days as vegetative growth parameters. As a parameter of generative growth, observations of flowering age, fruiting age, and harvest age were carried out. Crop production was determined from the parameters of the final weight of the biomass (wet and dry weight) and the weight of the harvest. Data for each parameters were analyzed by using One-Way ANOVA test at α=5%. To determine the differences among the three treatment levels, the analysis of Duncan multiple comparison was performed.

Measurement of the microclimate in the greenhouse was carried out as supporting data. Parameters of environmental conditions measured included temperature, humidity, wind speed, and the intensity of sunlight. Measurement of environmental parameters is done manually every 08.00, 12.00 and 16.00 WIB.

3. RESULTS AND DISCUSSION

3.1. Extreme Rainfall Index

Based on the trend analysis of the annual extreme rainfall indices in the eastern part of DI Yogyakarta in the period 1988-2019, dry conditions tend to increase every year while rainy days will tend to increase from year to year. This is indicated by the number of stations with a positive trend of the consecutive dry days (CDD) index and the dominance of the negative trend of the CWD index as shown in Figure 2. The R10mm and R20mm indexes which represent the frequency of heavy rains tend to experience an index trend that tends to increase every year. The rain intensity index, namely RX1day, RX5day, PRCPTOT, SDII, and R95p tends to increase every year. The same result was also revealed by Misnawati & Perdanawati (2019), namely an increase in the SDII, RX1day, R95p, R50mm indexes and a decrease in the CWD and R10mm indexes. This condition indicates that rainy days tend to decrease, but the frequency and intensity of heavy rains are increasing. Thus coditions are the basis for selecting the

Rnnmm frequency index and the Rxnnday frequency index as treatments in the simulation of rainfall for watering chili plants.

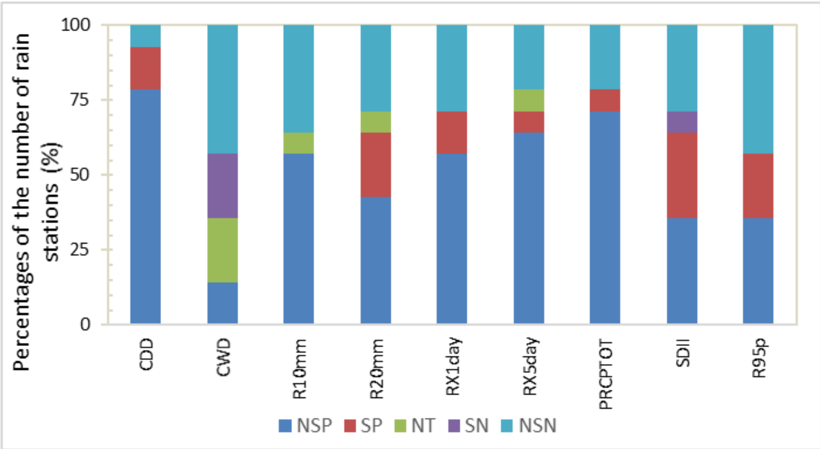
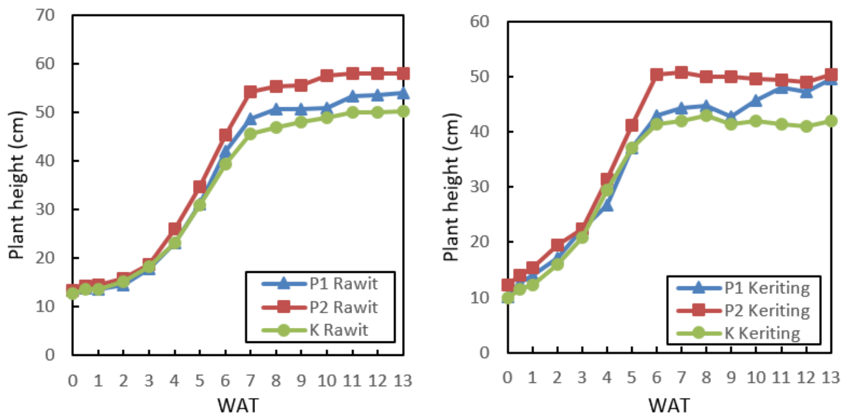


Figure 2. Percentage of the number of rain stations that have an annual index trend that is not significantly positive (NSP), significantly positive (SP), no trend (NT), significantly negative (SN), and significant not negative (NSN)

3.2. Chili Plant Growth

3.2.1. Plant Height

The growth of cayenne pepper plant height can be seen in Figure 3a where in the three treatments given, plant heights were not much different visually. In treatment P2, cayenne pepper had the highest value and the lowest was treatment K. Plant height growth increased exponentially at 0 to 7 weeks after transplanting (WAT). Height gain began to slow down when the plant was at 8 WAT. The same thing happened to curly chili (Figure 3b). The difference lays in the P1 treatment where plant height increased at the 9th of WAT.



(a) (b)

Figure 3. Plant Heights of (a) Rawit/Cayenne Pepper and (b) Keriting/Curly Chili

The average values of cayenne pepper plant height for all observations at each stage of growth were not significantly different at 0.05 level. This means that treatment of simulated extreme rainfall in our research conducted in period of May-June-July did not show a significant impact on the height of cayenne pepper plants. Various possibilities could be associated with this result such as dry period of the time and pot experiment setup. The months of May-June-July have gotten into the dry season already, that evaporation was so high preventing waterlogging even too much water was given to the media. Other possibility might correspond to the holed base of pot which facilitated the drainage under the pot, making media had in fact never saturated in a significant period of time. In order to deeply assess the true mechanism, we may need to do more precise research on this issue.

The same things happened to curly chili plants, that there was no significant different plant height among the treatments applied. Different watering in all treatments was started when the plants were 9 days old after planting, or at 2-13 WAT to be precise. Plant height was also not affected by the extreme rainfall simulations both in terms of intensity and frequency. Same factors, dry season and the holed base pot, could be associated to what happened to the curly chili plants.

Theoretically extreme rainfall can cause inundation because the volume of water accumulates rapidly in a short time especially for the land with bad drainage. Waterlogging due to bad drainage in chili plant cultivation or any others can worsen the health of chili plants such root rotten. Significantly negative impact of flooding treatments on chili plants was observed by (Safrizal *et al*., 2008). The situation of this research setup may be different from that of our research so the results are also different.

3.2.2 Number of Leaves

In Figure 4 a the number of cayenne pepper leaves decreased in P1 and P2 treatments at 8 WAP. In the P2 treatment the decrease in the number of leaves at 8 WAP was greater than in the P1 treatment. The main difference in these two treatments was that in P1 the plants were not watered every day while in P2 the plants were watered every day. This might result in the soil conditions in the P2 treatment experiencing saturation for several days. Changes in the number of leaves on curly chili can be seen in Figure 4b. The decrease in the number of leaves in the P1 treatment occurred at 7 WAP. In treatment P2 the number of leaves decreased at 8 WAP while in treatment K the number of leaves decreased at 9 WAP. But there was not much fluctuation in the number of leaves as compared to that in cayenne pepper.

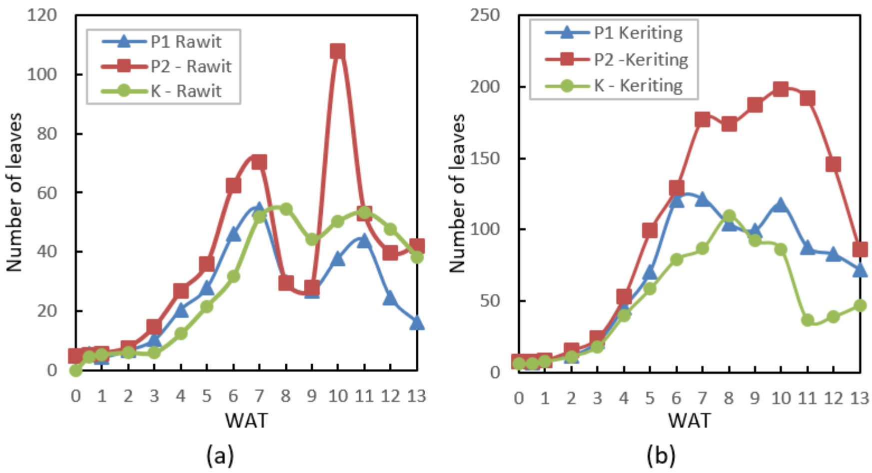


Figure 4. Number of leaves (a) cayenne pepper and (b) curly chili

Susilawati, *et al.* (2012) stated that red chili plants with inundation for 3 days resulted in leaf wilting. This is because the roots are rotting and destroyed so they are unable to absorb water and nutrients, especially N. In addition, wilted leaves indicate that the plant is unable to compensate for the transpiration process that occurs due to lack of oxygen in the roots. This causes the metabolism to occur anaerobically, thereby interfering with water uptake in plants.

3.2.3 Age of Flowering, Fruiting, and First Harvest

Flowering age of cayenne pepper and curly chili can be seen in Table 3. For cayenne pepper, the average ages of flowering in treatments P1 and P2 were the same, namely 39.67 days. Meanwhile, the K treatment was about 4 days longer, i.e. an average of 44.3 days. Based on the results of the one-way Anova test, the age of flowering in the three treatments was not significantly different. This means that the treatments of simulated rainfall intensity and frequency does not have a significant effect.

Table 3. Age of flowering, fruiting, and harvesting on cayenne and curly chilies with various treatments

Treatment	Cayenne pepper			Curly chili		
	Flowering Age (day)	Fruiting Age (day)	First Harvest Age (day)	Flowering Age (day)	Fruiting Age (day)	First Harvest Age (day)
P1	39.67	53.67	77.3	28,00	39,00	80,00[a]
P2	39.67	56	78.67	32,33	43,67	80,00[a]
K	44.3	66.5	77	24,00	37,00	82.33[b]
P-Value	0.661	0.233	0.754	0.512	0.236	0,000

For curly chili plants, the fastest flowering age was found in treatment K, when the plants were 24 days old on average. In the P1 treatment the plants began to flower at the age of 28 days. The longest age of flower emergence was found in P2 treatment, when the plant was 32.33 days old. However, based on the one-way Anova statistical test, the three treatments did not have a significant difference. Insani *et al.* (2021) stated that inundation for 3 days in curly chili varieties Jacko delayed flowering by 13%, and 26% when inundated for 10 days. In our research, the extreme rainfall simulation treatment might be not likely to cause inundation, so the delay of flowering time was not significantly different.

According to Ashari *et al.* (2014), the occurrence of extreme rainfall can increase the frequency of flowering in Siamese oranges. However, flowers that can develop into fruit are very few due to high rainfall and high soil water content that the metabolism of fruit formation is not optimal. In addition, high rainfall can cause changes in air temperature which play a role in energy activation or enzyme inactivation during fruit formation. In our research, such an incident did not occur because the watering was carried out with a dipper and not a spray treatment resembling real extreme rain.

The fruiting ages of cayenne pepper and curly chili for the three treatments did not show a statistically significant difference. The same thing happened to the age of the plants for the first harvest. However, for curly chili, the age of the first harvest for treatment P1 and P2 was significantly different from treatment K. In treatment K, the first harvest was 2 days longer than the other two treatments. This fact implied that the extreme rainfall treatment has caused the condition of the media moisture content to be quite different so the harvest time is slightly faster than in K treatment, although the P1 and P2 treatments were not significantly different.

3.2.4 Yields

The average yields of cayenne pepper and curly chili in the three treatments can be seen in Figure 5. In both plants, the yields in treatment P1 and P2 were greater than those in treatment K. However, the one-way Anova statistical test of the three treatments showed that the difference was not significant for both cayenne pepper and curly chili. Thus, it can be concluded that extreme rains in May-June-July can provide slightly higher yields (but not statistically significant) compared to CWR-based watering. According to Supriadi *et al.* (2018), irrigation of red chili plants with additions of up to kc x 5.ETo can increase fruit weight per plant. In our research, that the yields were not significantly different could probably be corresponded to the dry period (May -June-July) when evapotranspiration was so high that there is no fatal inundation.

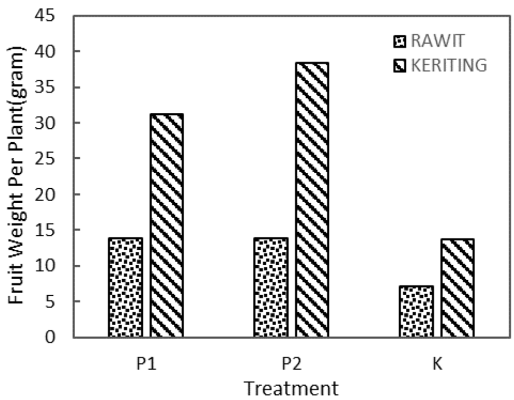


Figure 5. Average fruit weight of chili per plant in all treatments

The fruit yield of cayenne pepper suffers from fruit rot most likely due to anthracnose disease as shown in Figure 6. This disease is caused by several Colletotrichum fungi, including C. gleosporioides, C. acutatum, C. capsica. These fungal attacks can cause tissue damage in plants so that they experience physiological disturbances and can reduce productivity. Symptoms shown by this disease include the appearance of blackish brown spots on plants which will then expand and become soft rot (Semangun, 2007).

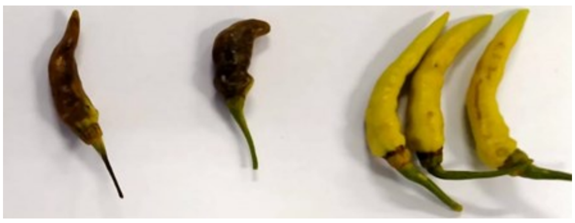


Figure 6. Cayenne pepper attacked by fruit rot disease

Anthracnose disease attacks the fruit of cayenne pepper in all treatments given. While in curly chili the disease does not attack. The attack of this disease increases when the environmental conditions are humid where the optimum temperature for the development of this fungus is 20-24^{o}C. The spread occurs through water splashes, both rainwater and spray equipment (Meilin, 2014). Therefore, in the rainy season, this disease attack can reduce crop yields by 50-100% (Santoni *et al*., 2016). In our research, root rot occurs not due to rain but due to excessive watering treatment. Even in the dry period (May-June-July), apparently the media conditions are sufficient for the development of Anthracnose.

3.2.5. Final Weight of Plant Biomass Fresh Weight

The total fresh weight of cayenne and curly chili plants in all treatments can be seen in Table 4. In cayenne pepper plants, the largest total fresh weight was found in P2 treatment, which was 96.14 grams. In the second order, there is treatment P1 with a weight of 83.25 grams. The lowest fresh weight was found in treatment K, which was 76.24 grams. The one-way ANOVA test on the fresh weight of cayenne pepper showed that the treatment given did not have a significantly different effect on the fresh weight of cayenne pepper plant biomass.

In curly chili plants, the total fresh weight of plants with P2 treatment had the highest value with a total fresh weight of 85.17 grams. In the second place is the P1 treatment with a weight of 78.33 grams. The lowest plant fresh weight was treatment K, which was 44.86 grams. However, the one-way ANOVA test showed that the total fresh weights of curly chilies were not significantly different.

Thus, it can be concluded that the extreme rains in May-June-July did not affect the total fresh weight of the plants. In the P2 treatment, which is a treatment based on the intensity of rainfall, it gives the largest fresh weight value. The P1 treatment which is a treatment based on the frequency of extreme rain also gives a greater value than the K treatment. The simulated extreme rainfall treatment may tend to raise soil moisture that could increase water content of plant biomass, but the dry air humidity period in May-June-July compensates so there is no severe damage to plants.

Table 4. Fresh weight of each plant part in cayenne pepper and curly chili

Cayenne Pepper				
Plant Part	**Treatment**			**P-Value**
	P1	**P2**	**K**	
Root	17.74	18.13	18.13	0.99
Stalk	30.72	49.42	30.38	0.46
leaves	20.96	13.80	20.54	0.74
fruit	13.83	13.92	7.19	0.52
Total fresh weight	83.25	96.14	76.24	0.84
Curly Chili				
Plant Part	**Treatment**			**P-Value**
	P1	**P2**	**K**	
Root	6.46	10.52	6.78	0.73
Stalk	22.83	24.67	13.69	0.71
leaves	17.91	11.59	10.63	0.70
fruit	31.12	38.39	13.75	0.57
Total fresh weight	78.33	85.17	44.86	0.70

3.2.6. Dry Weight

The comparison of the total dry weight of plants in cayenne pepper and curly chili can be seen in Table 5. In cayenne pepper, the dry weight of plants at the three treatments given did not differ significantly based on the results of the one-way ANOVA test. The average dry weight in treatment P1 and P2 is almost the same, namely 18.98 grams and 18.62 grams, while in K treatment the result is 16.93 grams.

For curly chili plants, the average dry weight for each treatment P1, P2 and K were 18.39 grams, 21.0 grams, and 9.19 grams, respectively. Although the difference in dry weight values looks large, the one-way ANOVA test shows there is no a significantly different effect on the dry weight of curly chili plants.

Table 5. Dry weight of each plant part in cayenne pepper and curly chili

Plant Part	**Treatment**			**P-Value**
	P1	**P2**	**K**	
Root	5.18	5.35	4.57	0.94
Stalk	7.58	8.62	7.43	0.92
leaves	4.40	2.52	4.27	0.61
fruit	1.81	2.13	0.67	0.15
Total fresh weight	18.98	18.62	16.93	0.96
Plant Part	**Treatment**			**P-Value**
	P1	**P2**	**K**	
Root	1.94	3.80	1.55	0.58
Stalk	5.79	6.65	3.14	0.66
leaves	1.90	2.49	3.82	0.64
fruit	6.83	8.07	2.60	0.57
Total fresh weight	18.39	21.00	9.19	0.65

4. CONCLUSIONS AND SUGGESTIONS

In general, cayenne pepper and curly chili were not significantly affected by extreme rainfall treatments bases on the parameters of plant height, number of leaves, age of flowering, fruiting, and final weight of the plant biomass, except for the age of the first harvest. This fact is probably of the high evapotranspiration can compensate for the high watering. Another possibility is that the experiment was carried out using pots with holes at the bottom so excessive water would be well drained. The position of the pot that is higher than the soil surface also contributed to preventing inundation. However, for cayenne pepper, the fruit was found to be susceptible to rot disease anthracnose when high humidity is introduced. This result implied that growing chilies in pots or in raised beds can mitigate the effects of extreme rainfall events.

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