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The Impact of Yellow Leaf Curl Disease Stage During Vegetative and Generative Phases on The Growth and Yield of Curly Red Chili Pepper OR Twist 42

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ABSTRACT

Curly chili (*Capsicum annum L.*) *is one of the vegetable commodities widely cultivated in Indonesia which has a high selling value. Although it has a high selling value, chili cultivation has many obstacles, one of which is the attack of pathogens that reduce the yield of curly chili, especially yellow curly leaf disease on agricultural land. Yellow curly leaf disease is always found in chili cultivation and is the main production obstacle in Indonesia that reduces the harvest. This study aims to see the impact of yellow curly disease attacks in the vegetative and generative phases on the growth and yield of curly red chili cultivation. The study was conducted from August 2023 to March 2024 using the field observation method from the beginning of growth to harvest. Observations were made by measuring the parameters of plant height, stem diameter, number of branches, number of productive branches, fallen flowers, fruit weight, fruit length and observation of yellow curly disease pathogens. The results of the study showed that attacks of yellow curly disease in the vegetative and generative phases had a significant effect on the growth parameters and yield of curly red chili plants. From the results of the analysis of yellow curly disease attacks in the vegetative phase, the number of fruits and fruit weight were lower, namely 10.90 and 32.04 grams/tree, compared to attacks in the generative phase which produced 24.27 and 77.67 grams/tree.*

1. INTRODUCTION

Chili plants are an agricultural commodity that contribute significantly to the Gross Domestic Product (GDP) by sector (Septiadi & Joka, 2019). Chili is commonly used by the public as a seasoning and spice in cooking. Curly red chili is one of the vegetable commodities widely cultivated in Indonesia. Central Java ranks as the second-largest chili-producing province in Indonesia, with a yield of 236,921 tons or 15.24% of the national production in 2023, following West Java (BPS, 2024). According to data from the Central Bureau of Statistics (BPS), per capita chili consumption among Indonesians increased in 2023. BPS recorded that in 2023, the average Indonesian consumed 0.0388 ounces of red chili per capita per week. This consumption rose by 5.9% compared to 2022, which was 0.0366 ounces per capita per week (BPS, 2024).

Like other cultivated plants, chili plants are susceptible to infections from pathogens that cause disease. One of the pathogens attacking chili plants, leading to decreased production, is the yellow leaf curl disease, which remains challenging to manage (Vivaldy *et al*., 2016). The yellow leaf curl disease is caused by a virus from the *Geminiviridae* family. Based on host range, geminiviruses are classified into four genus. The genus of geminivirus found in chili plants is *Begomovirus* (subgroup III), which is transmitted by the whitefly vector (*Bemisia tabaci*) that infects chili plants. Common *Begomovirus* strains infecting chili plants include the *Pepper yellow leaf curl virus* (PYLCV) and the *Tomato yellow leaf curl virus* (TYLCV). According to research by Wilisiani (2019), common symptoms of *Begomovirus* infection include vein clearing on the leaf blade, which then progresses to yellowing, thickening of the leaf veins, and curling of the leaves. In more severe cases, young leaves become small and curled, with bright yellow leaf blades, leading to stunted plant growth.

If an infection occurs during the early growth stage or vegetative phase, chili productivity will decrease, increasing the risk of crop failure. The potential reduction in chili yields due to viral infections varies depending on the location of infection, plant age at infection, growing season, and plant variety. The younger the plant at the time of infection, the higher the percentage of yield loss. Yellow leaf curl disease affects all developmental stages of the plant, but symptoms are most prominent in the vegetative phase. According to Lavenia (2021), plants infected during the vegetative phase show yellowing leaves, reduced leaf size, stunted growth, fewer branches, and flower buds that may fall off. In contrast, plants infected during the generative phase typically show yellowing only at the tips (yellow tuft), while uninfected parts can still flower and fruit. Based on this background, the researcher aims to observe the impact of yellow leaf curl disease transmission in the vegetative and generative phases on the growth and yield of curly red chili (OR Twist 42 variety) in a single growing season.

Research Benefits: This study will measure the impact of yellow leaf curl pathogen attacks in the vegetative and generative phases and based on the scale of damage on yield loss in curly red chili plants, OR Twist 42 variety.

2. MATERIALS AND METHODS

2.1. Place and Time

The research site is located on agricultural land at an altitude of 1,133 meters above sea level, with a plot size of 611 m². The study was conducted on a chili farm in Batur Village, Getasan Subdistrict, Semarang Regency, from August 2023 to March 2024. The tools used in this study include: hoes, rulers, drums, plastic mulch, stakes, hoses, tarpaulins, mulch hole-punchers, buckets, watering cans, plastic knives, plant sprayers, laboratory testing equipment, RH meters, thermometers, and UV plastic. The materials used in this study include OR Twist 42 chili variety, cow manure, NPK Mutiara 16:16:16, NPK Mutiara Grower, and water. Research implementation included several stages discussed in the following sections.

Figure 1. Research land plan

1. Seeding: (a) Seeds were first soaked in water for 5 minutes for sorting; (b) The seeds were then transferred to prepared seedling trays; and (c) The seeding medium was a mix of topsoil and cow manure in a ratio of 1:2.
2. Land preparation: (a) Soil was turn to make a soil bed; (b) Raised beds were made with a length of 12 m and width of 1 m, with a 50 cm distance between beds; (c) Soil was loosened, and 500 g of cow manure per planting hole was mixed using a hoe; and (d) Plastic mulch was placed on top of the beds, with spacing holes of 70 x 50 cm.
3. Planting: (a) Planting was done one week after applying the base cow manure fertilizer; (b). Good seeds of curly red chili were transplanted with a spacing of 70 x 50 cm (Kusumasari *et al*., 2022); and (c). Replanting is carried out up to 1 week after transplanting (WAT).
4. Fertilization: The fertilization (Table 1) was carried out 7 days before transplanting. (a) The fertilizers included cow manure, NPK Mutiara (16:16:16), and NPK Mutiara Grower; (b) The first fertilization used cow manure compost at a dose of 500 g/plant; (c) Follow-up fertilization was given after the curly red chili plants were 4-8 WAT, with a dose of 2 g/plant, applied by watering with 250 ml of water every two weeks; (d) At 9 WAT or more, NPK Mutiara Grower was applied at a dose of 5 g/plant, using the same volume of water (250 ml) every 2 weeks.
5. Maintenance, including staking and watering. (a) Staking was performed to help the plants grow upright, reduce damage from fruit weight and wind, and facilitate fertilization. Staking was done 2 WAT; (b) Watering was carried out every morning around the root zone. This aims to provide water for the plants to replace the lost through evaporation and absorption by the roots, ensuring optimal growth and production processes.
6. Disease observation: (a) Disease observations were conducted weekly since transplanting until the final harvest; (b) Disease assessment was based on the OPT-DPI 2018 guidelines; (c) No pest and disease control measures were implemented.
7. Harvesting: (a) Harvesting was conducted when the plants were between 93 to 120 days after transplanting (DAT), with the criteria that the fruit was red in color and the skin surface was smooth and shiny; (b) Harvesting was done in the morning after the dew has evaporated from the fruit's surface to prevent rotting.

Table 1. Fertilization period for curly red chili plants (Suherman *et al*., 2018; Hendarto *et al*., 2021)

Time / Fertilization Stage	Fertilizer Type	Dose	Notes
Base fertilization	Cow manure	500 g/plant	Mixed into planting media
Follow-up fertilizer (every two weeks from 4-8 MST)	NPK Mutiara 16-16-16	2 g/ plant	Applied via watering
Follow-up fFertilizer (every two weeks from ≥ 9 MST)	NPK Mutiara *Grower*	5 g/ plant	Applied via watering

2.2. Research Method

The observation method for the chili plants involves monitoring 480 plants in the field, distributed across a total of 27 beds measuring approximately 1×12 m, with a spacing of 1.2 m between beds and 0.7×0.5 m between chili plants. The land was first prepared by turning the soil with a hoe to a depth of 0.4 m. The land was measured using a measuring tape to create a bed layout pattern. The soil was supplemented with a base application of cow manure at a rate of 500 g per planting hole one month before the transplanting period. Follow-up fertilization with NPK Mutiara 16:16:16 (2 grams per planting hole) was applied in stages every two weeks during the growth (vegetative) phase, while NPK Mutiara Grower (5 g per planting hole) was provided every two weeks during the fruiting (generative) phase.

2.3. Observation Variables

2.3.1. Incidence and severity of yellow leaf curl disease

Symptoms of yellow leaf curl disease are characterized by noticeable changes in the plants, such as young leaves yellowing and spreading from the leaf tips down to the lower leaves, with thickened and curled leaf edges. The variation in symptoms can differ based on the plant's resistance and age. If infection occurs during the vegetative phase, the leaves yellow, the plants become stunted, and flower and fruit formation is hindered. If infection happens during the generative phase, only the upper parts of the plant show yellowing symptoms, while only the uninfected parts of the plant can produce flowers and fruits. In cases of severe infection, all leaves may turn completely yellow. These symptoms are observed in 27 beds, which contain 48 plots consisting of 28 plants each. From each group of 28 plants, 10 plants are selected as samples, resulting in a total of 480 sampled plants observed from the beginning of transplanting until the final harvest. The assessment of plant damage was based on the symptoms of pest attacks, which can be diverse. Plant damage can be absolute or non-absolute.

1. Pest and Disease Severity Intensity Formula

$$I = \frac{\sum_{1=0}^{Z} (ni \ x \ vi)}{Z \ x \ N} x100\% \quad (1)$$

where I is intensity of attack (%), ni is number of plants or parts of the sample plants with damage scale vi, N is total number of plants or parts of the sample plants observed, vi is value of the damage scale for the i^{-th} sample, Z is value of the highest damage scale. Damage was scored based on Ganefianti *et al*. (2008) as detailed in Table 2. According to Direktur Jenderal Tanaman Pangan (2018), the damage scale was classified into four categories as detailed in Table 3.

Table 2. Damage score values for plants affected by disease (Ganefianti *et al*., 2008)

Score	Remarks
0	Healthy plant
1	Yellow
2	Yellow and curled
3	Yellow, curled, and bending down and up
4	Yellow, curled, bending down and up, and the plant becomes stunted

Table 3. Damage scale values for plants affected by disease (Dirjen Tanaman Pangan, 2018)

Category/Scale	Disease Attack Level
Light	if severity level > AP ≤ 11%
Moderate	if severity level > 11 ≤ 25%
Severe	if severity level > 25 ≤ 85%
Total Loss	if severity level > 85%

2.3.2. Plant production

The production of chili plants is calculated based on the sum of weekly harvests from the initial harvest (18 WAT) to the final harvest (23 WAT). This provides the total chili harvest for one growing season.

2.3.3. Data analysis

The data from the observation of the intensity of the yellow curly leaf disease during the vegetative and generative phases in relation to plant production is analyzed using the analysis of variance method with a significance level of 5%. The relationship between the two variables is analyzed using correlation and simple regression. Data analysis is conducted using Microsoft Excel and SPSS.

3. RESULTS AND DISCUSSION

Figure 2 depicts the visual differences between healthy plants and virus-attacked plants. The geminivirus of the genus *Begomovirus* is the cause of the *Pepper yellow leaf curl virus* disease in chili plants. Infected plants can be easily identified by their unique symptoms, such as yellow and green mosaic patterns, leaves curling upwards/downwards, and stunted growth (Subiastuti *et al*., 2021).

3.1. Impact of Yellow Curl Disease Attack

The research results indicate that the impact of *Begomovirus* attacks during the vegetative and generative growth periods affects the number of fruits and average fruit weight. From the data analysis, the yellow curl disease attack during the vegetative phase resulted in a lower yield of 10.9 fruits/tree and 32.04 g/tree lower as compared to those of

Figure 2. Attack of yellow curl disease on (a) Vegetatif phase, (b) Generative phase, and (c) Healthy plant.

generative phase, which yielded 24.27 fruits/tree and 77.67 g/tree (Table 4). The yellow curl disease attack during the vegetative phase reduced fruit yield by 44.91% and fruit weight by 41.25% compared to the generative phase.

Koeda *et al.* (2016) stated that the intensity of yellow curl pathogen attacks during the generative phase is lighter compared to the virus attacks occurring during the vegetative phase. The symptoms caused by the geminivirus isolate vary depending on the timing of plant infection. Symptoms in *C. annuum* first appear on young leaves/tips as yellow spots around the leaf veins, which then develop into yellow leaf veins (vein clearing), becoming concave and curled with light mosaic or yellow coloration. Symptoms continue until almost the entire young leaf or tip turns bright yellow, with some displaying a mix of yellow and green, and the leaves becoming smaller, thicker, and curled (Subiastuti *et al*., 2021).

Table 4. Independent samples test

Description	Unit	Average		Std. Deviation		*t*-count	Sig. (2-tailed)
		Vegetative Phase	Generative Phase	Vegetative Phase	Generative Phase		
Yellow curl disease	%	81.19	63.83	12.87	7.72	8.008	0
Plant height	cm	39.00	51.56	11.29	10.76	8.408	0
Stem diameter	mm	7.67	9.58	1.534	0.87	7.526	0
Number of Branches	--	28.67	39.88	12.21	11.63	4.603	0
Productive branches	--	10.58	24.25	7.48	8.53	8.340	0
Fallen flowers	--	18.31	15.73	8.89	5.62	1.701	0.092
Number of fruits	--	10.90	24.27	7.64	8.50	8.105	0
Fruit weight	g	32.04	77.67	21.42	25.63	9.460	0
Fruit length	cm	11.77	13.46	3.71	1.28	2.974	0.004

3.1.1. Yellow curl disease

Table 4 shows that there is a significant difference in the average severity of yellow curl disease between the attack during the vegetative phase (81.19%) and the attack during the generative phase (63.83%). The p-value < 0.001 indicates a significant difference between the yellow curl attack in the vegetative phase and the generative phase.

3.1.2. Plant height

There is a significant difference in the average plant height during the attack in the vegetative phase (39.00 cm) and the height during the attack in the generative phase (51.56 cm). The p-value < 0.001 indicates a significant difference between plant height during the attack in the vegetative phase and the height during the attack in the generative phase.

3.1.3. Stem diameter

There is a significant difference in the average stem diameter during the attack in the vegetative phase (7.67 mm) and the diameter during the attack in the generative phase (9.58 mm). The p-value < 0.001 indicates a significant difference between the stem diameter during the attack in the vegetative phase and the diameter during the attack in the generative phase.

3.1.4. Number of branches

There is a significant difference in the average number of branches during the attack in the vegetative phase (28.67) and the number during the attack in the generative phase (39.88). The *p*-value < 0.001 indicates a significant difference between the number of branches during the attack in the vegetative phase and the number during the attack in the generative phase.

3.1.5. Productive branches

There is a significant difference in the average number of productive branches during the attack in the vegetative phase (10.58) and the number during the attack in the generative phase (24.25). The *p*-value < 0.001 indicates a significant difference between the productive branches during the attack in the vegetative phase and the productive branches during the attack in the generative phase.

3.1.6. Fallen flowers

There is no significant difference in the average fallen flowers during the attack in the vegetative phase (18.31) and the fallen flowers during the attack in the generative phase (15.73). The *p*-value > 0.005 indicates no significant difference between the fallen flowers during the attack in the vegetative phase and the fallen flowers during the attack in the generative phase.

3.1.7. Number of fruits

There is a significant difference in the average number of fruits during the attack in the vegetative phase (10.90) and the number of fruits during the attack in the generative phase (24.27). The *p*-value < 0.001 indicates a significant difference between the number of fruits during the attack in the vegetative phase and the number of fruits during the attack in the generative phase.

3.1.8. Fruit weight

There is a significant difference in the average fruit weight during the attack in the vegetative phase (32.04 g) and the weight during the attack in the generative phase (77.67 g). The *p*-value < 0.001 indicates a significant difference between the fruit weight during the attack in the vegetative phase and the weight during the attack in the generative phase.

3.1.9. Fruit length

There is a significant difference in the average fruit length during the attack in the vegetative phase (11.77 cm) and the length during the attack in the generative phase (13.46 cm). The *p*-value = 0.004 indicates a significant difference between the fruit length during the attack in the vegetative phase and the length during the attack in the generative phase.

From the observations in Table 4, it can be seen that the yellow curl disease attack during the generative phase results in lighter impacts in terms of severity, plant height, stem diameter, number of branches, productive branches, number of fruits, fruit weight, and fruit length compared to the yellow curl disease attack during the vegetative phase. According to Green & Wu (1991), the yellow curl attack during the vegetative phase has a more severe impact on growth parameters and yield, such as plant height, stem diameter, number of branches, productive branches, number of fruits, and fruit weight. *Begomovirus* attacks the meristematic parts of the plant, so if infected during the vegetative phase, it can lead to losses of up to 100%. According to Putri *et al.* (2018), yellow curl disease due to *Begomovirus* infection can occur in both the vegetative and generative phases, reducing both the quantity and weight of the fruits, leading to decreased harvest yields or even complete crop failure.

The presence of the whitefly (*Bemisia tabaci*) is a factor that spreads the *Begomovirus* vector, causing yellow curl disease. When whiteflies feed on infected plants, they take up virus particles and carry them into their gut. When they switch to feeding on healthy plants, they can transmit the virus through their saliva (Gadhave *et al*., 2020). The virus carried by whiteflies replicates in the nucleus and then moves from cell to cell through plasmodesmata. In the next phase, the virus moves from the cells to reach the phloem through the vascular system, resulting in the virus rapidly moving to the young leaves at the tips. At this stage, the leaves begin to show symptoms of turning yellow, curling, and, if the infection becomes severe, they may appear stunted (Dawson, 1999).

Geminivirus replication occurs within the nucleus of the host cell, where they enhance and redirect the host's DNA synthesis machinery. Some geminiviruses are limited to the phloem vascular tissue, while others are also found in mesophyll cells. All these cell types are fully differentiated and have therefore exited the cell cycle replication stage, implying that some factors necessary for viral DNA synthesis/replication are no longer produced. Geminiviruses can at least partially reprogram their host cell cycle to reinitiate the replication phase, benefiting from the cellular machinery required for DNA replication. This partial reprogramming is mediated by interactions between geminivirus proteins and cell cycle components (Bonnamy *et al*., 2023).

The replication and systemic movement of the virus cause morphological and ultrastructural changes in chili leaves. These changes are seen in the mesophyll and epidermal tissue of chili plant leaves. The cells become shorter, irregularly arranged, multi-layered, and more densely packed. Geminivirus infection also causes color changes in chili plant leaves. Virus infection in the mesophyll, palisade, and parenchyma tissues leads to leaf discoloration. Chlorophyll is present in these organs, so damage to them impacts leaf color and shape. This aligns with reports stating that healthy chloroplasts are attached to the mesophyll, palisade, and parenchyma cell walls, with elongated and dense cell structures (A'yuningsih, 2017). Consequently, chlorophyll formation is inhibited due to viral infection, causing the chlorophyll formation rate to be slower than chlorophyll degradation in the leaves (Funayama-Noguchi & Terashima, 2006).

Table 5. Correlation of growth and yield of curly red chili var. OR Twist 42 at different levels of attack in the vegetative phase

	KK	TT	DB	JC	CP	BG	JB	BB	PB
KK	1	-0.720**	-0.576**	-0.048	-0.412**	0.284	-0.479**	-0.625**	-0.358*
TT		1	0.671**	0.13	0.303*	-0.071	0.324*	0.445**	0.234
DB			1	0.265	0.414**	0.006	0.441**	0.472**	0.012
JC				1	0.688**	0.797**	0.648**	0.492**	-0.172
CP					1	0.113	0.959**	0.858**	0.107
BG						1	0.091	-0.044	-0.324*
JB							1	0.944**	0.141
BB								1	0.273
PB									1

Note: TT: Plant height; DB: Stem diameter; JC: Number of branches; CP: Productive branches; BG: Fallen flowers; JB: Number of fruits; BB: Fruit weight; PB: Fruit length; KK: Yellow curl

Table 6. Correlation of growth and yield of curly red chili var. OR Twist 42 at different levels of attack in the generative phase

	KK	TT	DB	JC	CP	BG	JB	BB	PB
KK	1	-0.232	-0.033	0.016	-0.182	0.313*	-0.178	-0.211	-0.11
TT		1	0.348*	0.232	0.323*	-0.013	0.323*	0.396**	0.193
DB			1	0.083	0.076	0.053	0.075	0.204	0.267
JC				1	0.886**	0.720**	0.887**	0.806**	-0.051
CP					1	0.318*	1.000**	0.930**	0.076
BG						1	0.320*	0.256	-0.223
JB							1	0.929**	0.076
BB								1	0.325*
PB									1

Note: Notations are same as in Table 5

From the data above, the following can be interpreted:

1. The Pearson correlation values between yellow curl disease and plant height in the vegetative and generative phases are -0.720 and -0.232, respectively. This indicates a negative correlation coefficient, meaning the two variables are inversely related. Thus, when the yellow curl disease variable is high, the plant height variable decreases. The impact of yellow curl pathogen is greater on plant height during the vegetative phase than in the generative phase. The relationship between yellow curl and plant height shows a strong negative correlation in the vegetative phase, while in the generative phase, the negative correlation is very weak.
2. The Pearson correlation values between yellow curl disease and productive branches in the vegetative and generative phases are -0.412 and -0.182, respectively, indicating a negative correlation coefficient. This means the two variables are inversely related; as yellow curl disease increases, the number of productive branches decreases. The relationship between yellow curl and productive branches in the vegetative phase shows a fairly strong negative correlation, suggesting that increased yellow curl infection significantly reduces the number of productive branches in chili plants. However, the relationship in the generative phase is very weakly negative, meaning that increased yellow curl infection in the generative phase has little impact on the number of productive branches in chili plants.
3. The Pearson correlation values between yellow curl disease and the number of fruits in the vegetative and generative phases are -0.479 and -0.178, respectively, indicating a negative correlation coefficient. This means the two variables are inversely related; as yellow curl disease increases, the number of fruits decreases. The relationship between yellow curl and the number of fruits in the vegetative phase shows a fairly strong negative correlation, suggesting that an increase in yellow curl infection significantly reduces the number of fruits on chili plants. However, the relationship in the generative phase is very weakly negative, meaning that an increase in yellow curl infection during this phase has little effect on the number of fruits on chili plants.
4. The Pearson correlation values between yellow curl disease and fruit weight in the vegetative and generative phases are -0.625 and -0.211, respectively, indicating a negative correlation coefficient. This means that as yellow curl disease severity increases, fruit weight decreases. The relationship between yellow curl disease and fruit weight in the vegetative phase shows a strong negative correlation, meaning that increased yellow curl infection significantly reduces fruit weight in chili plants. In the generative phase, the negative correlation is very weak, indicating that an increase in yellow curl infection during this phase has little effect on fruit weight. Yellow curl disease in curly chili plants can affect both the quantity and weight of fruits. According to Andianto *et al*. (2015), plants infected with yellow curl disease develop abnormal leaf formation, which disrupts photosynthesis and reduces photosynthate production, thus failing to support plant growth and development, especially in the fruit.
5. The Pearson correlation values between plant height and stem diameter in the vegetative and generative phases are 0.671 and 0.348, respectively, indicating a positive correlation coefficient. This means the two variables have a direct relationship; as plant height increases, stem diameter also increases. The relationship between plant height and stem diameter in the vegetative phase shows a strong positive correlation, meaning that increased plant height significantly impacts stem diameter in chili plants. In the generative phase, the correlation is moderately strong, indicating that increased plant height in this phase has a moderate impact on stem diameter in chili plants.
6. The Pearson correlation values between the number of branches and productive branches in the vegetative and generative phases are 0.688 and 0.886, respectively, indicating a positive correlation coefficient. This means that as the number of branches increases, the number of productive branches also increases. The relationship between the number of branches and productive branches in the vegetative phase shows a strong positive correlation, suggesting that an increase in the number of branches significantly impacts productive branches in chili plants. In the generative phase, the correlation is very strong, indicating that an increase in the number of branches during this phase has a substantial impact on the number of productive branches in chili plants.
7. The Pearson correlation values between productive branches and the number of fruits in the vegetative and generative phases are 0.959 and 1.000, respectively, indicating a positive correlation coefficient. This means both variables are directly related; as the number of productive branches increases, the number of fruits also increases. In the vegetative phase, the relationship between productive branches and the number of fruits shows a very strong

positive correlation, suggesting that an increase in productive branches significantly impacts fruit quantity in chili plants. In the generative phase, the correlation is perfect, meaning that any increase in productive branches during this phase directly results in an increase in the number of fruits in chili plants.

The coefficient of determination is a measure indicating the extent to which the variability in the production variable (i.e., the number of chili fruits) can be explained by the variables Yellow Leaf Curl (X1), Plant Height (X2), Stem Diameter (X3), Number of Branches (X4), Productive Branches (X5), Fallen Flowers (X6), Fruit Weight (X7), and Fruit Length (X8). In other words, this coefficient is used to assess how well these factors (X1 to X8) explain the production variable.

Table 7. Calculation results of the determination coefficient (R square) for the vegetative phase model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.992[a]	0.984	0.981	1.06272

Predictors: (Constant), (Constant), Fruit Length (X8), Stem Diameter (X3), Number of Branches (X4), Yellow Leaf Curl (X1), Plant Height (X2), Fruit Weight (X7), Productive Branches (X5), Fallen Flowers (X6)

Table 8. Results of the determination coefficient calculation (r square) for the generative phase model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	1.000	0.14401

Predictors: (Constant), Fruit Length (X8), Number of Branches (X4), Yellow Curl (X1), Plant Height (X2), Stem Diameter (X3), Flower Drop (X6), Fruit Weight (X7), Productive Branches (X5)

Based on the SPSS output in Tables 7 and 8, the calculated R values for the vegetative and generative phases are 0.992 and 1.000, respectively. This indicates that the influence of the X variables on the Y variable is 99.2% and 100%. This shows that the percentage of variation in the yield of chili peppers explained by the variation of the eight independent variables during the vegetative phase is 99.2%, while the remaining 0.8% is explained by other variables outside the study; during the generative phase, the eight independent variables explain 100%.

The analysis method used in this research is multiple linear regression. This multiple regression analysis aims to determine the extent of the influence of Yellow Curl (X1), Plant Height (X2), Stem Diameter (X3), Number of Branches (X4), Productive Branches (X5), Fallen Flowers (X6), Fruit Weight (X7), and Fruit Length (X8) on the variable Fruit Quantity (Y) during the vegetative and generative phases. This study utilizes computer software in the form of SPSS, as shown in Table 9 and 10.

From the regression results in Table 9, it was found that in the vegetative phase, the variables of plant height (X1) with a significance value of 0.011, productive branches (X5) with a significance value of 0.001, and fruit weight (X7) with a significance value of 0.000 were significant. Since the significance values are less than 0.05, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, indicating a significant relationship between plant height, productive branches, and fruit weight with the number of fruits (Y). In the generative phase, as shown in Table

Table 9. Results of multiple linear regression test during the vegetative phase

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
	B	Std. Error	Beta		
(Constant)	-0.305	2.839		-0.107	0.915
Yellow Curl (X1)	0.006	0.022	0.01	0.266	0.792
Plant Height (X2)	-0.08	0.03	-0.094	-2.662	0.011
Stem Diameter (X3)	0.268	0.158	0.054	1.702	0.097
Number of Branches (X4)	-0.605	0.309	-0.965	-1.956	0.058
Productive Branches (X5)	1.092	0.301	1.069	3.633	0.001
Fallen Flowers (X6)	0.641	0.311	0.745	2.059	0.046
Fruit Weight (X7)	0.201	0.018	0.563	1.1281	0
Fruit Length (X8)	-0.054	0.049	-0.026	-1.107	0.275

Tabel 10. Results of multiple linear regression test in generative phase

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-0.297	0.475		-0.625	0.536
Yellow Curl (X1)	0.005	0.003	0.005	1,764	0.086
Plant Height (X2)	0.004	0.005	0.002	0.771	0.445
Stem Diameter (X3)	-0.034	0.04	-0.004	-0.858	0.396
Number of Branches (X4)	0.017	0.05	0.023	0.331	0.743
Productive Branches (X5)	0.987	0.05	0.99	19.677	0
Fallen Flowers (X6)	-0.016	0.051	-0.01	-0.309	0.759
Fruit Weight (X7)	-0.002	0.003	-0.005	-0.538	0.594
Fruit Length (X8)	0.012	0.024	0.002	0.484	0.631

10, the variable of productive branches (X5) has a significance value of 0.000. Because this significance value is also less than 0.05, H0 is rejected and H1 is accepted, indicating a significant relationship between productive branches and the number of fruits (Y).

4. CONCLUSION

Based on the results of the study discussing the impact of yellow curl disease transmission during the vegetative and generative phases on the growth and yield of curly red chili cultivation variety OR Twist 42 in a single growing season period using SPSS analysis model, the following conclusions can be drawn:

1. There are significant differences in the average growth (plant height, stem diameter, number of branches, productive branches) and yield (number of fruits, fruit weight, and fruit length) of plants affected during the vegetative and generative phases. There is no significant difference in fallen flowers. The attack of the yellow curl pathogen during the vegetative phase reduces fruit yield by 44.91% and fruit weight by 41.25% compared to attacks during the generative phase.
2. The yellow curl disease in the vegetative phase has a strong negative correlation with the parameters of plant height (-0.720), stem diameter (-0.576), and fruit weight (-0.625), and a moderately strong negative correlation with the parameters of productive branches (-0.412), number of fruits (-0.479), and fruit length (-0.358). In the generative phase, the yellow curl disease shows a very weak negative correlation with the parameters of plant height (-0.232), stem diameter (-0.033), productive branches (-0.182), number of fruits (-0.178), fruit weight (-0.211), and fruit length (-0.110).
3. The results of the multiple linear regression analysis indicate that the factors influencing the growth and yield of chili peppers during the attack of yellow curl pathogens in the vegetative phase are the variables of plant height (X1) with a significance level of 0.011, productive branches (X5) with a significance level of 0.001, and fruit weight (X7) with a significance level of 0.000. In the generative phase of yellow curl disease, the variable that affects growth and yield is the productive branches (X5) with a significance level of 0.000.

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