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Phenological Diversity of Four Varieties and Harvest Yields of Zucchini (*Cucurbita pepo* L.) with Different Concentration of Gibberelin

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Abstract

Zucchini plants contain several vitamins such as vitamin B complex, vitamin C, vitamin A, fiber and potassium which can maintain human health. However, of the many nutritional contents contained, zucchini is still not widely known by the public. The relationship between phenology and several varieties of zucchini plants can add information about the appearance and results of each variety of zucchini plants in terms of plant phenology so that zucchini production can be maximized. The experiment designed used Randomized Block Design with 8 treatment and 4 replication, namely $G_0V_Z = 0$ ppm, Zacky Z-6; $G_0V_C = 0$ ppm, Carissa; $G_0V_B = 0$ ppm, Black Scoop; $G_0V_S = 0$ ppm, Shuky; $G_{150}V_Z = 150$ ppm, Zacky Z-6; $G_{150}V_C = 150$ ppm, Carissa; $G_{150}V_B = 150$ ppm, Black Scoop and $G_{150}V_S = 150$ ppm, Shuky. The results show that the phenological diversity of four varieties with different gibberellin concentration showed significant differences, where the gibberellin concentration treatment could accelerate the aging phase of plants in four varieties compared to the treatment without gibberellin. In addition, growth parameters in the form of fresh and dry weight with the Carissa variety had the best growth compared to other varieties, but were not significantly different from the Black Scoop variety. The increased growth in the Carissa variety with 150 ppm gibberellin treatment was directly proportional to the increase in harvest yield, include fruit set, total of fruit and fruit weight.

Keywords: Phenological, Zucchini, Gibberelin, Heat Unit, Growth Degree Days

1. Introduction

Zucchini plants contain several vitamins such as vitamin B complex, vitamin C which is good for preventing aging and increasing immunity in the body, vitamin A which acts as an antioxidant, contains fiber which is good for regulating blood sugar levels, also contains potassium which can reduce blood pressure, prevent heart disease and stroke (Ashriyani *et al.*, 2022) ^[6]. Zucchini also contains several other bioactive compounds, such as phenols, flavonoids, amino acids, and minerals (Bannayan *et al.*, 2017) ^[7]. However, of the many nutritional contents contained, zucchini is still not widely known by the public. This is because most zucchini varieties come from introductions or abroad, such as the Zacky Z-6, Carissa, Black Scoop and Shuky varieties, so research is needed on growth tests and results of four zucchini varieties. Varieties that come from introductions or abroad may not necessarily grow outside their habitat. One of the criteria that can be used to determine the growth and development of a plant is through plant phenology. Plant phenology studies include every activity starting from observation, recording and interpretation at every stage of the plant life cycle, including germination to plant aging (Koch *et al.*, 2009) ^[15]. Zucchini plant production can be maximized in various ways, one of which is by administering plant growth regulators. Plant hormones or ZPT (Plant Growth Regulators) can stimulate, inhibit or change physiological pathways in plants. This is because ZPT in low doses will affect the development or metabolism process in plants (Rademacher, 2015) ^[22]. ZPT can control plant growth and development and affect physiological pathways in responding to environmental stimuli for plant survival (Davies, 2010) ^[10]. One type of ZPT that can stimulate growth, especially in the flowering process, is the gibberellin hormone.

Gibberellin can regulate metabolic pathways in plants. Therefore, gibberellin can regulate plant responses, such as seed germination, stem and root maturation and increased leaf area and flowering in plants (Al-harhi *et al.*, 2021) ^[5]. The relationship between phenology and several varieties of zucchini plants can add information regarding the appearance and results of each variety of zucchini plants in terms of plant phenology so that zucchini production can be maximized. In addition, administering gibberellin at an optimum dose is expected to maximize the growth and yield of zucchini plants.

Materials and Methods

Study area

The research was conducted in January-March 2025 located in Dresel Hamlet, Oro-Oro Ombo Village, Batu District, Batu City, East Java Province. Batu City has an average air temperature of 22.2 °C with an annual rainfall of 2028 mm in 2022 (BPS, 2023). The research location point is located at 7°54'35"S 112°31'34"E, a plain with an altitude of 1005 meters above sea level. Laboratory analysis for plant growth observation and analysis for fruit quality was carried out at the Land and Environmental Resources Laboratory and Physiology Laboratory, Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang.

Research design

The research was designed using a Randomized Block Design (RBD) consisting of 8 treatments and repeated 4 times to obtain 32 treatment combination units. Combination of treatments between different varieties and gibberellin concentrations, namely G₀V_Z = 0 ppm, Zacky Z-6; G₀V_C = 0 ppm, Carissa; G₀V_B = 0 ppm, Black Scoop; G₀V_S = 0 ppm, Shuky; G₁₅₀V_Z = 150 ppm, Zacky Z-6; G₁₅₀V_C = 150 ppm, Carissa; G₁₅₀V_B = 150 ppm, Black Scoop and G₁₅₀V_S = 150 ppm, Shuky. Polybags measuring 40 x 40 cm and obtained a total of 384 plants. The number of plants obtained at a distance between polybags of 25 cm x 25 cm per plot is 12 plants, the distance between plots is 50 cm x 50 cm.

Data collection method

a. Micro climate

Microclimate observations are carried out to determine the amount of heat received by plants, in the form of growth degree days and heat units. GDD (Growth Degree Days) observations are carried out periodically with two-day intervals by observing the accumulation of heat absorbed by each zucchini variety. Meanwhile, the duration of heat unit achievement in several phases can be based on zucchini phenology, starting from the germination phase to the harvest phase. Heat units are based on the GDD formula, but are specific to the plant growth phase sequentially (Subronto *et al.*, 1990) ^[28]. The tool used for microclimate observation is the Elitech Temperature Data Logger RC-4 which can store maximum and minimum temperature data automatically. GDD calculations are presented in equation 1

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base} \quad \text{Equation 1}$$

Note:

T_{max} = Maximum air temperature observed at 12.30 pm
T_{min} = Minimum air temperature observed at 05.00 am
T_{base} = Base temperature, 10 °C (Ida *et al.*, 2019) ^[14].

b. Plant growth

Plant growth observations were conducted consisting of fresh and dry weight. Fresh weight is done by weighing the part of the plant that does not bear fruit. Dry weight is done by putting the part of the plant that does not bear fruit into the oven for 48 hours then weighing it, observations are made at the age of 45 DAP.

c. Plant yield

1. Fruit Set

Fruitset observation is carried out by calculated the percentage of female flowers that turn into fruit. According to Warisman and Eko (2022) ^[32], fruitset uses the following formula (Equation 2):

$$\text{Fruit set} = \frac{\text{Total of fruits formed}}{\text{Total of female flowers}} \times 100\% \quad \text{Equation 2}$$

2. Total of Fruit (fruit plant⁻¹)

Observation of the total fruits is carried out by counting the number of fruits on each plant as a whole from the beginning to the end of the harvest.

3. Fruit Weight (g)

Observations of fruit weight⁻¹ and fruit weight plant⁻¹ were carried out by weighing the fruit cumulatively from the beginning to the end of the harvest using a digital scale.

Data analysis

The data obtained were analyzed using analysis of variance or F test with a level of 5%. If there is a significant effect of the treatment, then a comparison test will be continued using the Least Significant Difference Test (LSD) at a level of 5% to determine the differences between treatments. The data obtained were tested using analysis of variance or F test at the 5% level. The further test of group data comparison is continued using the Least Significant Difference (LSD) at the 5% level when indicated a significant different.

Result and Discussion

Micro climate

Based on the research that has been conducted, it can be seen that the heat unit achievement in the phenological diversity of four varieties with treatments without gibberellin (Figure 1) did not differ significantly at the beginning of planting, but at the time of fruit emergence there was a significant difference. This is because temperature, light, humidity and other factors in the microclimate greatly affect the accumulation of heat units required by plants, especially in the flowering phase. Research conducted by Lucio *et al.* (2021) ^[17], where in the early phase, all varieties were in similar microclimate conditions, so there was no significant difference in terms of heat unit achievement. However, differences began to appear when the microclimate affected the critical phase of fruit formation.

Diversity of varieties affects the achievement of heat units so that each variety has a different heat unit as well. For example, the Black Scoop variety only requires a heat of 354 °C to produce female flowers, compared to other varieties that require a total heat of 367 °C. Based on this, it can be seen that varieties that are adaptive to microclimate conditions will reach each stage of their growth phase faster until harvest compared to other varieties (Adrianton *et al.*, 2024) ^[4]. The effect of phenological diversity of four varieties with a

gibberellin concentration of 150 ppm on heat units also looks significantly different, but the total heat absorption is less than the treatment without gibberellin. This is because the gibberellin hormone can accelerate the transition from the vegetative phase to the generative phase. Research conducted by Viciana *et al.* (2019) [31], it was proven that when certain varieties were applied with gibberellin, the rate of GDD accumulation became faster. In addition, this study explained that different zucchini varieties responded to temperature variations, where varieties that were more adaptive at certain temperatures showed more optimal GDD achievements. In addition, research conducted by Demir and Celikel (2021) [11] found that varieties that had a better response to climate change showed increased accumulation of GDD and heat units which are very important for early growth and fruit formation.

Based on the research that has been done, the total heat accumulation or total days obtained by four varieties of zucchini with treatment without gibberellin compared to the treatment of gibberellin concentration of 150 ppm has a significant difference (Figure 1), where the total heat accumulation or total days obtained by four varieties of zucchini with gibberellin treatment is less or faster than the treatment without gibberellin. Gibberellin is known as a

hormone that can stimulate cell growth and faster cell division, where in plants given gibberellin hormone causes the flowering and fruiting phases to occur earlier and faster. Ranwala and Miller (2008) [23] showed that gibberellin application can increase the activity of carbohydrate-digesting enzymes that support faster cell growth so that plants can accumulate GDD more efficiently.

Gibberellin also functions as a direct regulator in many plant hormone signal pathways that affect plant growth and development. Research conducted by Chen and Qiu (2022) [8] found that gibberellin produces a physiological response, where optimal signal levels from gibberellin can accelerate various metabolic and growth processes that can ultimately accelerate GDD. Gibberellin can also function to stimulate root growth and development by increasing the activity of meristematic cells in the root zone. Research by Shtin *et al.* (2022) [27] shows that gibberellin promotes cell proliferation in the root meristem, which supports the formation of healthier and more efficient roots in absorbing water and nutrients. Thus, plants that receive gibberellin treatment tend to have strong, responsive and adaptive root systems when faced with non-ideal conditions, such as excessive heat accumulation.

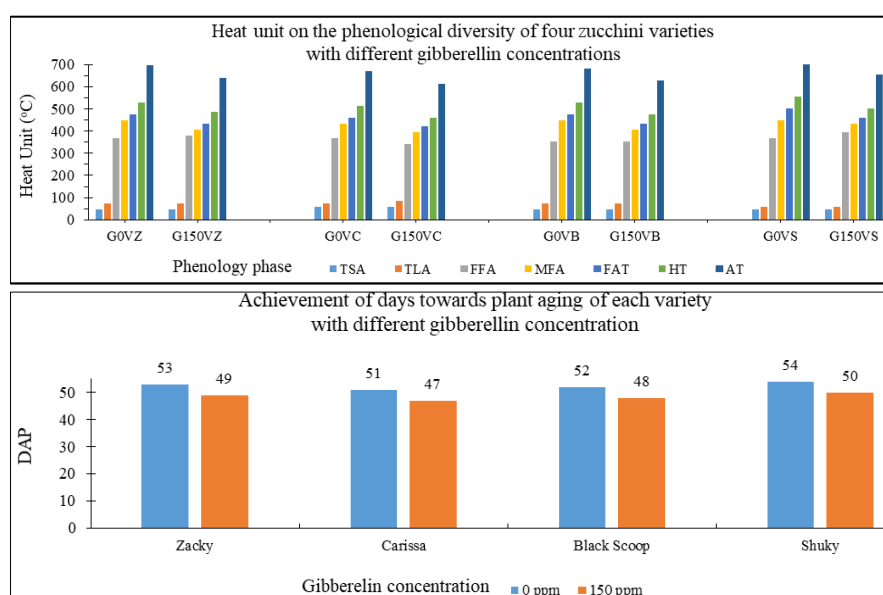


Fig 1: Micro climate effects of treatment; a. heat unit on the phenological diversity of four zucchini varieties with different gibberellin concentration, b. Days toward plant aging of each variety with different gibberellin concentration. TSA = Time Shoof of Appear, TLA = Time Leaf of Appear, FFA = Female Flower of Appearance, MFA = Male Flower of Appearance, FAT = Fruit of Appearance Time, HT = Harvest Time and AT = Aging Time.

Plant growth

The results of the analysis of variance showed a significant effect on the parameters of fresh weight and dry weight of plants on the phenological diversity of four varieties with gibberellin concentrations. The effect of phenological diversity of four varieties with gibberellin concentrations on fresh weight and dry weight of plants at the age of 45 DAP is shown in Table 1.

Based on Table 1, it can be seen that there is a real effect on the increase in gibberellin concentration in each variety on the fresh weight parameter of plants aged 45 DAP, where the V_Z , V_C , V_B and V_S treatments with 150 ppm gibberellin treatment have heavier plants with an increase of 23.49; 25.05; 21.86 and 19.09% respectively compared to the

treatment without gibberellin in each variety. Meanwhile, the difference in varieties at each gibberellin concentration, V_C treatment in the treatment without gibberellin and gibberellin concentration of 150 ppm had plants that were 60.70 and 97.79 g plant⁻¹ heavier compared to V_B and V_S treatments. The increase in gibberellin concentration in each variety was significantly different in the dry weight parameters of plants aged 45 DAP, where the V_Z , V_C , V_B and V_S treatments with gibberellin concentration treatment of 150 ppm had heavier dry weights with an increase in weight of 11.03; 10.37; 9.94 and 8.44% respectively compared to the treatment without gibberellin in each variety. When viewed in terms of differences in varieties at each gibberellin concentration, the V_C treatment in the treatment without gibberellin had a

heavier dry weight of 3.61 and 5.44 g plant⁻¹ compared to the V_B and V_S treatments.

The genetic characteristics and responses of each variety to fresh weight and dry weight values have significant differences. The Carissa variety has higher fresh weight and dry weight values than other varieties. This is because Carissa has increased vegetative growth performance and has a larger

leaf area. Adnan *et al.* (2021) ^[2] highlighted that genetic variation in soybean varieties can affect the fresh weight and dry weight of plants. In addition, more adaptive varieties usually have higher weights. As the results of a study conducted by Yuniansyah *et al.* (2022) ^[33], varieties that are more responsive to the environment tend to produce higher weights, both fresh weight and dry weight.

Table 1: Effect of phenological diversity of four varieties with gibberellin concentration on fresh weight and dry weight at 45 DAP

Gibberelin (ppm)	Fresh weight (g plant ⁻¹)			
	Variety			
	V _Z	V _C	V _B	V _S
0	395.5 bc	403.3 c	364.1 ab	341.4 a
150	488.4 e	504.3 e	443.6 d	406.5 cd
LSD (5%)	37.25			
KV (%)	6.050			
Gibberelin (ppm)	Dry weight (g plant ⁻¹)			
	Variety			
	V _Z	V _C	V _B	V _S
0	44.88 ab	46.93 bc	43.83 a	42.75 a
150	49.83 de	51.80 e	48.19 cd	46.36 bc
LSD (5%)	2.206			
KV (%)	6.200			

Note: Numbers accompanied by the same letters in the same column indicate no significant difference based on the 5% LSD test, tn = no significant difference, DAP = Days After Planting

Plant yield

1. Fruit Set

The average fruitset due to gibberellin administration on the phenological diversity of the four varieties is presented in Table 2.

The phenological growth pattern of each variety has its own characteristics. This phenology then affects the flowering and fruiting time (Nikolic *et al.*, 2012) ^[20]. Based on the results of the research that has been done (Table 2), the fruitset of each variety or each gibberellin concentration is not significantly different. This is because each variety has the same ability to produce fruit (in this case the number of fruits). Fruitset is

closely related to the pollination pattern applied (Rocha *et al.*, 2007) ^[24]. In the flowering phase of zucchini plants, it can be done by self-pollination or with the help of pollinating insects. The author applies self-pollination so that the fruitset produced by each variety does not look significantly different. Furthermore, Rocha *et al.* (2007) ^[24] explained that self-pollination occurs before the flower opens which is called closed pollination or cleistogamy. This is done to minimize pollinating insects taking pollen from male flowers, so that the pollination process can be maximized.

Table 2: Average fruit set due to gibberellin concentration on phenological diversity of four varieties

Gibberelin (ppm)	Fruit set (%)			
	Variety			
	V _Z	V _C	V _B	V _S
0	67.54	73.44	71.28	65.42
150	75.92	83.94	80.95	70.88
LSD (5%)	ns			
KV (%)	9.420			

Note: Numbers accompanied by the same letters in the same column indicate no significant difference based on the 5% LSD test, tn = no significant difference, DAP = Days After Planting

2. Total of Fruit (fruit plant⁻¹)

The results of the analysis of variance showed a significant effect on the number of fruit parameters on the phenological diversity of four varieties with gibberellin concentrations. The effect of phenological diversity of four varieties with gibberellin concentrations on the number of fruit parameters is presented in Table 3. The number of fruits is closely related to the flowering phase of a plant, where the more flowers on

a plant, the greater the increase in the number of fruit parameters. Each zucchini variety has different developmental characteristics, which can affect the number and size of fruit produced. This is supported by research (Sumarlin *et al.*, 2018) ^[30], it was found that phenological variations of each variety can result in different times in the flowering and fruiting phases.

Table 3: Effect of phenological diversity of four varieties with gibberellin concentration on the total of fruits

Gibberellin (ppm)	Total of Fruit (fruit plant ⁻¹)			
	Variety			
	V _Z	V _C	V _B	V _S
0	2.750 ab	3.418 c	3.168 bc	2.500 a
150	3.333 c	4.250 d	3.918 d	3.000 bc
LSD (5%)	0.469			
KV (%)	9.700			

Note: Numbers accompanied by the same letters in the same column indicate no significant difference based on the 5% LSD test, tn = no significant difference, DAP = Days After Planting

3. Fruit weight

Effect of phenological diversity of four varieties with gibberellin concentration on the fruit weight parameter is presented in Table 4. The increase in gibberellin concentration in each variety showed a significant effect on the parameters of fruit weight per fruit and fruit weight per plant, where the V_Z, V_C, V_B and V_S treatments with 150 ppm gibberellin treatment had heavier fruit with an increase of 8.80; 9.47; 7.99 and 7.36% respectively in the fruit weight parameter per fruit and 32.13; 36.54; 36.05 and 29.09% respectively compared to the treatment without gibberellin in each variety.

When viewed in terms of differences in varieties at each gibberellin concentration, the V_C treatment in the treatment without gibberellin and 150 ppm gibberellin concentration had a heavier fruit weight per fruit of 23.61 and 32.18 grams compared to the V_S treatment. Meanwhile, in terms of fruit weight per plant, the V_C treatment in the treatment without gibberellin and gibberellin concentration of 150 ppm had a heavier fruit weight per plant of 238.8 and 354.9 grams and 364.2 and 540.4 grams compared to the V_Z and V_S treatments. Fruit development begins when the flower crown falls off until the fruit is physiologically ripe. Fertilization occurs when the pollination process is successful, which is indicated by the flower crown slowly wilting, drying and falling off (Mulyawati and Na'iem, 2004) [19]. Fruit formation can be influenced by the effectiveness of pollinators, endogenous factors and environmental factors (Nurtjahjaningsih *et al.*, 2012) [21]. In addition, fertilization can occur when pollen pollinates the pistil, so that seed and embryo formation is accompanied by fruit formation (Lolaei *et al.*, 2013) [16]. External factors can also affect the size of the fruit of zucchini plants, such as the location of the fruit. This is in line with Daulay's statement (2020) [9], which states that the location of cucumber fruit growth affects the length of the fruit, where fruit that grows directly in the leaf axils is usually relatively longer and has a smooth texture.

The results of the study showed that the weight of zucchini fruit per fruit and per plant with a gibberellin concentration of 150 ppm was greater than the treatment without gibberellin. This is in accordance with the results of the study by Suhartono *et al.* (2020) [29], that the weight of cucumber fruit per fruit tends to be higher in the treatment given gibberellin concentration. The results of the study conducted by Adnyesuari *et al.* (2015) [3], showed that gibberellin with a concentration of 300 ppm gave the best results on the parameters of cucumber plant fruit weight. Research by Gosai *et al.* (2020) [13] showed that gibberellin application significantly increased the length and diameter of cucumber fruit in certain varieties.

Stated that the administration of gibberellin can increase root length, root diameter and root weight of plants (Selim *et al.*, 2009) [26]. Root structure is related to more efficient absorption of water and nutrients (Rogers and Benfey, 2015) [25]. This has a positive correlation with fruit development, especially fruit weight per fruit and per plant. Increasing gibberellin concentration has been shown to increase zucchini harvest variables, especially the parameters of fruit weight per fruit and per plant. The increase in zucchini yield due to gibberellin concentration of 150 ppm can be associated with increased leaf area growth and plant dry weight so that photosynthesis can run optimally. Increased growth, including plant physics, leaf morphology and transport tissue related to plant physiological processes such as light reception, photosynthesis, photosynthate transport and photosynthate storage will determine the yield and biomass of the plant (Mathan *et al.*, 2016) [18].

Gibberellin will increase photosynthate translocation and the transformation of sucrose into glucose, thereby encouraging extracellular invertase leading to the phloem to send carbohydrates to the sink organ, thereby increasing yields (Abbas *et al.*, 2020) [1]. Increasing photosynthate translocation through gibberellin administration will increase fruit growth and development. The diversity of phenological varieties greatly affects the fruit weight parameter. Research conducted by Fidiyawati *et al.* (2024) [12] on zucchini plants found that in three different varieties then evaluated based on fruit size and plant yield, where varieties with better adaptation to local conditions tend to produce larger fruits. Carissa variety has the highest fruit weight per plant, which is 1067.4 g. This is very proportional to the results of the research conducted, where the Carissa variety produces a heavier fruit weight per plant, which is 1103 g plant⁻¹

Table 4. Effect of phenological diversity of four varieties with gibberellin concentration on fruit weight.

Gibberellin (ppm)	Variety	
	V _Z	V _C
0	315.0 ab	323.6 ab
150	342.7 cd	354.3 cd
LSD (5%)	12.5	
KV (%)	3.96	

Gibberellin (ppm)	Variety	
	V _Z	V _S
0	864.7 ab	1103.4 ab
150	1142 d	1506.4 d
LSD (5%)	125.5	
KV (%)	14.52	

Note: Numbers accompanied by the same letters in the same column indicate no significant difference based on the 5% LSD test, tn = no significant difference, DAP = Days After Planting

Conclusion

Based on the results of the research that has been conducted, the phenological diversity of four varieties with different gibberellin concentrations showed a significant effect on the microclimate, growth, yield and quality of zucchini plants. In this regard, it can be concluded that four zucchini varieties

have significant differences based on the phenological phase, where the V_C and V_B treatments require a long time for shoots and open leaves to appear. However, both varieties have a longer flowering duration and a faster harvest time, thus stimulating faster plant aging compared to the V_Z and V_S treatments. V_C treatment with a gibberellin concentration of 150 ppm only requires a heat of 613 °C to reach the plant aging phase, compared to V_C treatment with a treatment without gibberellin of 669 °C. V_C treatment with a gibberellin concentration of 150 ppm can also provide the best growth and results. In addition, the $G_{150}V_C$ treatment significantly increased the fruit weight per plant by a percentage of 36.54% compared to the G_0V_C treatment. In addition, the Carissa variety in the treatment without gibberellin showed a heavier fruit weight per plant of 354.9 g compared to the Shuky variety. The Carissa variety is the best adaptive variety, seen from the parameters of heat units, GDD, growth and yield.

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