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Growth and Yield Response of Several Zucchini (*Cucurbita Pepo* L) Varieties to Auxin Application in The Midland in Tropical Area

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Abstract

Zucchini (Cucurbita pepo L.) is a short-lived vegetable plant with a harvest period ranging from 28 to 60 days after planting. It offers health benefits and has the potential for development in Indonesia, although it faces challenges, particularly because it thrives better in highland areas. This research aims to identify adaptive zucchini varieties for medium-altitude areas and evaluate the effect of auxin (IAA) on the growth and yield of zucchini in these regions. The study employed a split-plot design, with the main plots being varieties (P1, P2, P3) and the subplots being auxin concentrations (A0, A50, A100, A150 ppm). Observed variables included plant length, leaf number, stem diameter, leaf area, flowering age (male and female), number of flowers (male and female), number of fruits per plant, fruit weight per plant, as well as fruit length and diameter. The results indicated that the Carissa variety adapted best, producing a fruit weight per plant of 1,067.40 g. Additionally, auxin application increased the fruit weight per plant compared to those without auxin.

Keywords: Auxin; Tropical area; Variety; Zucchini

INTRODUCTION

Vegetable consumption in 2018 was 1.0414 kg per capita 1 week-1, increasing to 1.1209 kg per capita 1 week-1 in 2021, an increase of 7.63% (Buletin Konsumsi Pangan, 2021). Short-lived vegetable plants are needed to accelerate the fulfillment of weekly vegetable needs. One of the short-lived vegetable plants is zucchini (*Cucurbita pepo* L). The development of zucchini in Indonesia is a challenge in itself. This is because zucchini is suitable if grown in the highlands (Kusumiyati et al., 2019), which has a range of air temperatures of 12-30,8 ºC. The optimal planting area conditions for zucchini are in the highlands, while the area of the highlands in Indonesia planted with various highland vegetables is as large as 154.092 ha (Ritung, Sofyan, Erna Suryani, D. Subardja, Sukarman, Kusumo Nugroho, Suparto et al., 2015). Based on this, efforts are needed to develop it extensively by expanding the cultivation area in other plains such as medium plains.

Efforts to increase zucchini production in the medium plains that can be used are the use of adaptive varieties and auxin as a growth regulator to increase zucchini fruit production in the medium plains. Adaptive varieties will differ in each particular growing environment (Mastur &

Lestari, 2021). Several varieties have been developed in Indonesia, namely, Jacky Z-6 (Falah et al., 2019). Meanwhile, the growth regulator substance auxin increases the number of female flowers, which increases zucchini production. Therefore, both can be used as strategies to increase zucchini production to meet consumer needs. Based on this background, this research aims to determine adaptive varieties for medium plains and the effect of auxin on the growth and yield of zucchini plants in medium plains.

METHODS

The research was carried out from October 2023 to May 2024 at Tawangargo Village, Karangploso District, Malang Regency, East Java. The Divided Plot Design method was used with two factors. The Main Plot is a variety consisting of Jacky Z-6 (P1), Balizu (P2), and Carisa (P3). Subplots are differences in IAA concentration with 4 levels, namely: without PGR (A0), IAA 50 ppm (A50), IAA 100 ppm (A100), and IAA 150 ppm (A150), and replicated 3 times. Observation variables include plant height at age, number of leaves, stem diameter, leaf area, number of female flowers, number of male flowers, time when male flowers appear, time when female flowers appear, fruit diameter, fruit length, and fruit weight. The data obtained was analyzed. Using ANOVA, and if there were significant differences, it would be tested further, using HSD 5%, using ms. Excel.

RESULTS AND DISCUSSION

Plant growth

Zucchini is well adapted to tropical areas in the highlands or according to its native growing environment. Observation results show that plant length with 150 ppm IAA yields 36.79% higher than other IAA concentrations at plant age. 30 HST (Table 1). This follows the statement from (Meena, 2021) that the auxin hormone works by stimulating certain types of proteins in the plant's plasma membrane to pump ions H+ toward the cell wall and initiates cell elongation under conditions of IAA stress on *Cucurbitaceae*. In branch formation, the role of auxin in *cucurbitacea* is in regulating branching shoots through transporter genes.

Table 1. Plante height, number of leaves, and stem diameter of zucchini varieties and IAA concentration

Treatments	Plant height (cm)				Number of leaves				Stem diameter (cm)			
	10	20	30	40	10	20	30	40	10	20	30	40
	DAP (days after planting)											
Varieties												
P1	7,61	11,5	15,81	19,53	3,58	8,31	11,7	13,2	4,33	6,32	7,37	11,91
P2	8,67	12,9	16,26	20,67	4,03	7,81	11,3	13,6	4,54	6,65	7,21	12,17
P3	9,47	13,6	17,25	20,69	3,5	8,36	12	13,9	4,93	6,52	7,5	12,02
HSD (5%)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Concentration of IAA												
A0	7,67	11,5	14,00a	18,74	3,48	8,07	11,1	12,9	4,17	6,09	6,63	11,77
A50	8,44	12,3	14,94ab	20,04	3,52	8,11	11,3	12,4	4,59	6,32	7,68	12,05
A100	8,7	13,2	17,67ab	21,19	3,78	8,33	11,9	14,4	4,67	6,7	7,65	12,38
A150	9,52	13,6	19,15b	21,22	4,04	8,11	12,4	14,4	4,97	6,87	7,49	11,95
HSD (5%)	ns	ns	4,97	ns	ns	ns	ns	ns	ns	ns	ns	ns

In higher temperature conditions, auxin also plays an important role in maintaining plant root growth. *Cucurbitacea*, as in cucumbers and melons, stimulates the growth and development of lateral and adventitious roots emerging from the stem and root tissue (Steffens & Rasmussen, 2016). When plants are cultivated in conditions unsuitable for their original growing environment, strategies are needed to achieve optimal production, including applying a plant growth regulator. Auxin is reported to influence plant growth because auxin's main function is to stimulate plant cells' growth and differentiation.

Analysis of variance on leaf area parameters did not show any interaction between variety and IAA concentration on age 10, 20, 30, and 40 DAP. Separately, the variety of treatments did not show significant differences in mean leaf area at all ages. On the other hand, the IAA concentration treatment provided a significant difference in leaf area at age 20 and 30 DAP but did not provide a significant difference at age 10 and 40 DAP. The average leaf area based on various treatments and IAA concentrations can be seen in Table 2.

Observation of the initial time for male flowers to appear shows no difference in yield. The same thing happens to the time when female flowers appear, where all varieties show the same time when female flowers appear. The number of male flowers also showed no difference in yield. The number of female flowers showed different results, where the female flowers of the P1 variety were fewer than the P2 and P3 varieties. In the auxin treatment, the A0 treatment showed the lowest number of female flowers compared to the other treatments. (Table 3).

Table 2. Leaf area of zucchini varieties and IAA concentration

Treatments	Leaf area (cm^2 tan^{-1}) at age (DAP)			
	10	20	30	40
Varieties				
P1	287,6	1395, 7	2565	3025,1
P2	287	1373,4	2615,4	3293,5
P3	293,5	1327,3	2764,3	3238,8
HSD (5%)	ns	ns	ns	ns
Concentration of IAA				
A0	275	1185,5 a	1872,2 a	2860
A50	281,3	1222,9 ab	2625,1 ab	3159,7

A100	302,2	1467,8 ab	2987,9 ab	3262,6
A150	299,2	1585,6 b	3107,8 b	3461
HSD (5%)	ns	391,1	824,9	ns

Table 3. Number of male and female flowers, time of male and female flowers of zucchini varieties, and IAA concentration

treatments	number of flowers (flower plant^{-1})		time to flower (AP)	
	male	female	male	female
Varieties				
P1	10,44	3,70 a	30,08	26,91
P2	9,82	4,17 b	31,03	28,76
P3	10,07	4,72 b	30,72	27,75
HSD (5%)	tn	0,824	tn	tn
Concentration of IAA				
A0	9,63	2,40 a	31,41	29,41
A50	10,19	4,65 b	30,44	27,54
A100	10,22	4,91 b	30,59	26,76
A150	10,41	4,52 b	30	27,52
HSD (5%)	tn	1,245	tn	tn

An increase in environmental temperature in the middle plains causes plants to experience stress, which disrupts plant growth. High temperatures can cause heat damage due to ROS production and negatively impact plant growth and, as a consequence, cucumber yields (Ren et al., 2023). The response to high-temperature stress is a complex response depending on the duration and severity of the stress and the plant species. Changes and responses to thermal stress imposed on plants occur at all functional levels of the organism, which are initially reversible but can become permanent. Even if stress conditions are temporary, plant vitality decreases with the duration of the stress (Singh et al., 2019).

The effect of auxin on leaf enlargement has been reported several times (Sharif et al., 2022). One of them is in cucumber, through genetic screening and Mut Map analysis mapping a single recessive gene that codes for PINOID kinase protein (Csa1M537400), active in auxin transport, as a candidate gene responsible for the rl mutation that causes changes in leaf size. Plants treated with auxin transport inhibitors NPA (1-Nnaphthylphthalamic acid) showed similar leaf phenotypes to the rl mutant, further validating the involvement of IAA in leaf development (Sharif et al., 2022). The study results showed that treatment A150 gave the highest leaf area compared to other treatments. This also aligns with research (Vanneste & Friml, 2009), which states that plant hormones are in low quantities and often not synthesized where they react, so it is necessary to provide endogenous hormones so plants can grow and develop in optimal growth environments in non-optimal environments. Of course, adding auxin to each variety will cause a different

response.

The number of female flowers showed different results, where the female flowers of the P1 variety were fewer than the P2 and P3 varieties. In the auxin treatment, the A0 treatment showed the least number of female flowers compared to the other treatments. (Table 3). This is influenced by genetics and the variety's adaptation to its growing environment, as well as the application of growth hormones. Different genetic factors in zucchini varieties can cause different processes in the growth and development of plant cells, including organ formation, such as the number of flowers produced. Previous research on tomato plants was carried out by (Park et al., 2012). Tomato genes related to flowering start time are tailored to the best varieties for each commodity. Female flowers appear first, including fruit without pollination (*unpollinated*), usually called parthenocarpic fruit. These parthenocarpic fruits have weaknesses, especially in producing seeds or seeds, but they have advantages in increasing high-quality fruit products, usually very profitable horticultural crops (Rezaldi et al., 2019); for example, *C. pepo* sub. texana can produce more than one female bud on each axillary shoot and is included in the germplasm, which increases crop yields (Bannayan et al., 2011).

Yield

The yield and quality of zucchini are influenced by environmental and genetic factors. The zucchini varieties that have been released in Indonesia are still very limited and are only suitable for planting in the highlands, so cultivation strategies need to be implemented, one of which is by plant growth regulator, namely auxin. Every plant growth regulator will form various growth and morphogenetic responses that are pleitropic to its impact. Auxin is involved in various growth responses, such as apical dominance, cell division and growth, organic responses, fruit setting, and stimulatory responses (Debitama et al., 2022). The three varieties used have certain advantages, such as early maturing, producing lots of (small) fruit, and large fruit. Plant yield is closely correlated with the flowers produced by the plant. One of the characteristics of flowers of *Cucurbitaceae* is unisexual, almost no flowers in this family are unisexual. The corolla and calyx are sticky, while the corolla tube grows with the calyx. Flowers of *Cucurbitaceae* usually have five sepals and petals united or detached from the stamen (Olson et al., 2014).

The number of female flowers is correlated with plant production, if the number of female flowers is greater, the yield obtained will also be higher. The results showed that the number of female flowers formed differed between varieties, as did the auxin treatment (IAA) treatment A0 (without IAA) gave the lowest results compared to the others, this illustrates that auxin can increase the number of female flowers. Previous research reported that genetic factors and ethylene are ways to increase female flowers in zucchini (Boualem et al., 2015). Recent research shows that an increase in the number of female flowers in *Cucurbitacea* is by administering auxin ZPT, through the mechanism of increasing biosynthesis and the amount of endogenous ethylene (Niu et al., 2022). The influence of auxin on the endogenous regulation of ethylene biosynthesis has been

reported in many studies on plant growth and development. Auxin and ethylene influence each other in fruit ripening. High concentration of IAA in peaches (*Prunus persica* L.) necessary for ethylene biosynthesis during fruit ripening, exogenous auxin may increase ethylene synthesis and fruit ripening, possibly through increased expression of ethylene-synthesizing genes (ACS) and genes that respond to ethylene (ERF) (Pan et al., 2015). In *Arabidopsis thaliana*, administration of exogenous auxin can significantly increase the expression of AtACS4 and induce more ethylene. These studies show the effects of exogenous auxin treatment on ethylene synthesis differently in several plant species.

Table 4. Number of fruits, fruit weight, fruit length, fruit diameter of zucchini varieties, and IAA concentration

Treatments	Number of fruits (fruit plant^{-1})	Fruit weight (g plant $^{-1}$)	Fruit weight (g)	Fruit lenght (cm)	Fruit diameter (cm)
varieties					
P1	2,48	863,50 a	337,74 b	21,25 b	5,03 a
P2	2,85	837,50 a	291,88 a	18,02 a	5,02 a
P3	2,77	1067,40 b	379,44 c	20,78 b	5,49 b
CV %	3,01	2,73	2,07	2,95	1,27
Concentration of IAA					
A0	2,20 a	642,06 a	281,36 a	18,89	4,82 a
A50	2,80 ab	963,27 b	343,24 b	20,19	5,14 ab
A100	2,85 ab	1014,53 b	356,88 b	20,44	5,48 b
A150	2,96 b	1071,34 b	363,94 b	20,56	5,28 ab
CV %	6,03	6,43	3,21	3,59	2,91

Recent research shows that an increase in the number of female flowers in *Cucurbitacea* is due to the administration of auxin ZPT through the mechanism of increasing biosynthesis and the amount of endogenous ethylene (Niu et al., 2022). The influence of auxin on the endogenous regulation of ethylene biosynthesis has been reported in many studies on plant growth and development. Auxin and ethylene influence each other in fruit ripening. High concentration of IAA in peaches (*Prunus persica* L.) necessary for ethylene biosynthesis during fruit ripening, exogenous auxin may increase ethylene synthesis and fruit ripening, possibly through increased expression of ethylene-synthesizing genes (ACS) and genes that respond to ethylene (ERF)(Pan et al., 2015). In *Arabidopsis thaliana*, administration of exogenous auxin can significantly increase the expression of AtACS4 and induce more ethylene. These studies show the effects of exogenous auxin treatment on ethylene synthesis differently in several plant species.

The three zucchini varieties planted (P1, P2, and P3) have different phenotypic characteristics as genetic expressions that are the advantages of each variety. The jacky variety (P1) is the variety most widely planted in Indonesia because it is early maturing 18 – 21 DAP in the highland; Bisi Zu

(P2) has the advantage of small fruit, while Carissa (P3) has the advantage of large fruit size. All varieties are adaptive in the highlands or >800 mdpl. The results of harvest observations showed that variety treatment did not affect the number of fruit.plant^{-1}, but has a significant effect on fruit weight (g. plant^{-1}), fruit weight (g), length and diameter of fruit. Meanwhile, IAA treatment had a significant effect on the number of fruits.plant^{-1}, fruit weight (g. plant^{-1}), fruit weight (g), dan fruit diameter. So, the yield of zucchini plants in the midlands depends on the adaptive capacity of each variety or the application of growth hormones.

CONCLUSION

The variety and concentration of auxin (IAA) influence zucchini growth, yield, and quality in the midlands. Varieties influence according to their genetic advantages, while the application of auxin causes optimization of the plant's genetic potential. The number of male zucchini flowers was higher than that of female flowers, respectively, with 10.41 flowers tan-1 and 4.91 flowers tan-1. The Carissa variety adapted well, with a fruit weight per plant of 1,067.40 g ton-1. Providing auxin (IAA) increases the yield of fruit weight per plant by more than without auxin.

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