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Worm castings and naphthaleneacetic acid in the growth and yield of zucchini in shade houses

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ABSTRACT

The cultivation of zucchini (*Cucurbita pepo* L.) under protected conditions has limitations, such as low fruit set due to poor pollination, which affects the commercial yield and crop profitability. This research was carried out to assess the influence of earthworm humus (HL) and naphthaleneacetic acid (ANA) on the growth and yield of two zucchini cultivars in shade houses. A randomized block experimental design with eight treatments and 10 repetitions was used. The treatments influenced plant height, leaf area index, stem dry weight, leaf dry weight, plant dry weight, and fruit set; However, there were no differences because of the treatments in stem diameter, leaf greenness, and number of leaves. With the HMX58 cultivar, the highest plant height was obtained: while because of the Prestige cultivar, the highest index of leaf area, dry weight of leaves, and dry weight of the whole plant. The highest yield was obtained with the HMX58+LC treatment, while the fruit set and the number of fruits increased because of earthworm humus. The diameter and weight of the fruit increased because of ANA in both cultivars and the length of the fruit in the Prestige cultivar.

Keywords: Cucurbita pepo L.; dry weight; fruit length; fruit set; protected agriculture.

INTRODUCTION

The utilization of composts and worm castings is a cultural and ecological practice that improves the conditions of agricultural soils (Villegas-Cornelio and Laines, 2016) and induces an increase in the commercial yield of crops (De la Cruz-Lázaro *et al.*, 2009; Blouin *et al.*, 2019).

Besides containing essential nutrients for plants, worm castings have a positive effect on the porosity, aeration, and soil water retention capacity, contributing to the maintenance and development of microflora and microfauna, increasing the availability and root's nutrients assimilation (Aremu *et al.*, 2015; Zanor *et al.*, 2018). They stimulate soil biochemical reactions that promote the emergence, flowering, and fruiting of plants (Ramos *et al.*, 2019; Steffen *et al.*, 2019), since they produce substances with phytohormonal effects (Domínguez *et al.*, 2010), such as indoleacetic acid, gibberellic acid, and kinetin (Ravindran *et al.*, 2016).

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Phytohormones present in worm castings play an important role in regulating various plant growth processes (Zhang *et al.*, 2015; Wong *et al.*, 2020). Auxins promote cell elongation, inhibit primary root growth, mediate the response to tropisms, repress organ abscission, and induce floral and fruit development; Gibberellins regulate plant growth, seed germination, stem elongation, reserves mobilization, as well as their floral and fruit development; and cytokinins stimulate cell division, activate bud sprouting, induce organogenesis and delay senescence (Jordán and Casaretto, 2006).

The exogenous application of plant growth regulators depends on several factors such as the plant genotype, growing season, type of regulator, and applied concentration (Tantasawat *et al.*, 2015). Some have been widely used on vegetables, to improve fruit setting and increase production, such as indoleacetic acid (Montaño-Mata and Méndez-Natera, 2009), gibberellic acid (Pichardo-González *et al.*, 2018), naphthaleneacetic acid (Soriano-Melgar *et al.*, 2020; Sedighehsadat *et al.*, 2021), β-naphthoxyacetic acid (Martínez *et al.*, 2016) and forchlorfenuron (CPPU) (Rueda-Luna *et al.*, 2018). In this sense, naphthaleneacetic acid has been widely used in melons (Barzegar *et al.*, 2015; Menchaca-Ceja *et al.*, 2018), however, its effect on zucchini is scarcely known.

Regarding cucurbit cultivation in Mexico, zucchini (*Cucurbita pepo*) occupies the third place in economic importance (3,386 million pesos, MXN), preceded by the cucumber (*Cucumis sativus*) and watermelon (*Citrullus lanatus*). The states of Sonora and Puebla occupy first and second place in cultivated zucchini areas, with 6,200 and 3,889 ha, respectively. The third, Sinaloa has a 2,426 ha planted area, second place in production (78,215 t), and first place in yield (32.28 t ha^{-1}), 40% above the national average (SIAP, 2021).

However, staking cucurbit cultivation in protected conditions, regardless of using specific techniques to improve zucchini production, is scarcely researched in Mexico. Therefore, the objective of this research was to evaluate the effect of applying worm castings to soil and naphthaleneacetic acid via foliar spraying on the growth and yield of zucchini under shaded housing conditions.

MATERIALS AND METHODS

The experiment took place within a crop protection structure, shade house type, at the experimental field of the Facultad de Agronomía of the Universidad Autónoma de Sinaloa, located at 24° 48’ 30” NL, 107° 24’ 30” WL, 38.54 m altitude. The soil analysis, carried out before cultivation indicated that the soil had a clay texture and low organic matter content (Table 1). Culiacán, Sinaloa, has a BS1(h’)w(w)(e) climate: very warm semi-dry, extreme with summer rains, with less than five percent partial winter precipitation regarding the annual total (García, 2004). The mean temperature (21.9 °C) and relative humidity (69.5%) were recorded using thermohygrometers (DT171, Twilight) during the crop cycle (11/16/2019 to 03/04/2020), these were within optimal ranges (18 to 24 °C and 65 to 80% relative humidity) for zucchini cultivation (Molinar *et al.*, 1999; Cortés, 2003).

The soil was prepared and beds were formed 1.8 m apart from each other, to half of which worm castings were applied (Table 1). Subsequently, double irrigation tape and white/black coextruded polyethylene mulch were placed on top of each bed. Sowing was

Table 1. Physicochemical and microbiological characteristics of the soil and worm castings.

Analysis		Floor	Earthworm humus
Physical parameters:	pH 1:1 (H_2O)	7.85	5.98
	CE (dS m^{-1})	0.58	7.75
	PS (%)	79	96
	MO (%) Walkley-Black	1.21	26.49
	Sand (%)	21	77
	Silt (%)	20	16
	Clay (%)	59	7
Cations: (cmol+ kg^{-1})	Na^+ (Ac. NH4 pH 7)	2.2	0.91
	K^+ (Ac. NH4 pH 7)	0.22	2.11
	Ca^{2+} (Ac. NH4 pH 7)	2.32	43.16
	Mg^{2+} (Ac. NH4 pH 7)	0.78	13.57
Anions: (mg kg^{-1})	N-NO_3^- (Brusina)	0.97	3.4
	P-PO_4^- (Bray I)	0.06	0.29
	S-SO_4^{2-} (Turbidimeter)	0.12	50.43
Phytobeneficial: (ufc g^{-1} o propágulos g^{-1})	Aerobic bacteria (BK)	266 667	3 400 000
	Anaerobic bacteria (BK)	116 667	913 333
	Bacillus sp. (BK)	243 333	1 666 667
	Actinomycetes (AN)	100 000	233 333

conducted in 128-cavity polystyrene trays filled with peat (Brown 025W, Kekkila). The transplant took place on November 16, 2019, in an 11,820 plants per hectare density.

The Steiner (1984) solution at 50% was supplied for crop nutrition, from the transplant until the first flower anthesis, the complete solution was added later. Irrigation was applied when the tensiometers (2725ARL, Soil Moisture Equipment) placed at 0.30 m depth of the soil indicated moisture tensions from 20 to 25 kPa.

A randomized block experimental design with a 2A×2B×2C factorial arrangement was used, with eight treatments and 10 repetitions. Factor A corresponded to zucchini: Prestige cultivar, of the "green zucchini" type, and HMX586429 (HMX58), of the "gray zucchini" type. Factor B corresponded to the worm humus (WH) applied to the soil at a rate of 0 and 10 t ha^{-1}. Factor C was naphthaleneacetic acid (ANA), sprayed at 0 and 50. mg L^{-1} doses.

The treatments (interaction A×B×C): Prestige+worm castings+naphthaleneacetic acid (T1=Prestige+WH+ANA), Prestige+worm castings (T2=Prestige+WH), Prestige+naphthaleneacetic acid (T3=Prestige+ANA), Prestige (T4=Prestige), HMX586429+worm castings+naphthaleneacetic acid (T5=HMX58+WH+ANA), HMX586429+worm castings (T6=HMX58+WH), HMX586429+naphthaleneacetic acid (T7=HMX58+ANA) and HMX586429 (T8=HMX58) were established with ten repetitions in a 250 m^2 experimental area, with three plants as a useful plot.

The evaluated growth variables were: plant height (PH), with a measuring tape; stem diameter (SD), using a digital vernier (6MP, Truper); number of leaves per plant (LN); foliar greenness index (FG), with a portable chlorophyll meter (SPAD 502, Minolta), leaf area index (LIA) in leaf area m^2 per soil surface m^2, obtained by dividing the foliar area per each plant occupied surface (0.81 m^2), each leaf foliar area was estimated with the equation:

$$FA = 4.77 + \left(0.61 \times \text{width}^2\right),$$

following Rouphael *et al.* (2006). The stem dry weight (SDW), leaves (LDW), and plant (PDW), obtained at the end of the crop cycle (109 days after transplanting), were also evaluated with a precision balance (CP622, Sartorius), after drying the plant material in an electric oven (292, Felisa) at 70 °C until constant weight.

Regarding zucchini production, the fruits were collected between 5 and 7 days after anthesis and the number of fruits (NF) per plant was counted, with which the following was determined:

$$\text{Percentage of fruit setting}\left[FS(\%) = \left(\frac{\text{number of fruits with length } \geq \text{ 127 mm}}{\text{number of female flowers}}\right) \times 100\right];$$

fruit diameter (FD) and length (FL), using a digital vernier (6MP, Truper); fruit weight (FW), with a precision scale (CP622, Sartorius), yield (Molinar *et al.*, 1999; USDA, 2016) and fruit lag.

The obtained data were assessed with an analysis of variance and Tukey's multiple means comparisons test ($p \leq 0.05$) using version 7.0 STATISTICA statistical analysis software (StatSoft, 2004).

RESULTS AND DISCUSSION

Plant height was only affected by the cultivar factor (Table 2) since HMX58 exceeded ($p \leq 0.05$) the plant height of the Prestige cultivar by 53.6%. This obtained plant height concurs with Román-Román *et al.* (2022), who also observed greater height in HMX58 cultivar plants, compared to those of the Prestige cultivar. Dasgan and Bozkoylu (2007), Díaz *et al.* (2016) and Ayala-Tafoya *et al.* (2020) recorded heights of 210.9 to 288.3, 76, and 53.2 cm, under greenhouse environments, in 'Alata Yesili', 'Spineless Perfection' and 'Obsession' pumpkin plants, respectively. All of this coincides with Loy (2004), who points out the considerable morpho-physiological variation between pumpkins (*Cucurbita* spp.) and even between same species cultivars.

The cultivar factor also significantly influenced ($p \leq 0.05$) the stem diameter and leaf greenness (SPAD); although in both cases, without statistical differences ($p \leq 0.05$) due to the effect of the treatments. The stem diameter and leaf greenness index, observed during the evaluation period, indicate adequate plant vigor (Mendoza *et al.*, 1998; Swiader and Moore 2002; García-Bañuelos *et al.*, 2016) and concur with that reported on both variables by Ayala-Tafoya *et al.* (2020) and Román-Román *et al.* (2022).

Likewise, neither the number of produced leaves per plant (62.9 to 67) during the evaluation period nor the number of leaves (LN) that remained on the plants (22.7 to 26.3), after five pruning (de-leafing), were significantly affected by the treatments (Table 2). To avoid photosynthates loss in lower senescent leaves, reduce *Oidium* sp inoculum and the immature *Bemisia tabaci* population (Román-Román *et al.*, 2022), four to six leaves/plant were pruned every 12 to 14 days, thereby maintaining a more or less constant leaf density from 40 days after transplanting (dat) on, which is similar to the number of leaves (22 to 26) reported by Monares-Gallardo *et al.* (2012) and Román-Román *et al.* (2022).

The leaf area index was significantly influenced by the cultivar and naphthaleneacetic acid factors, as well as by the cultivar × WH interaction. The highest leaf area index was obtained with the Prestige treatment plants, statistically equal to the response induced by Prestige+WH, HMX58+WH, and Prestige+ANA, which exceeded from 41.2 (HMX58+ANA) to 118.2% (HMX58) that obtained in the rest of the treatments (Table 2). The leaf area index obtained with 'Prestige' is similar to that reported by Rouphael and Colla (2005) in 'Aphrodite' zucchini plants in greenhouse conditions (LAI of 2.7 m^2 m^{-2}) and Román-Román *et al.* (2022) with the same cultivar. The observed differences in the leaf area index also concur with Loy (2004), who reports considerable morpho-physiological variation between *Cucurbita pepo* cultivars.

Table 2. Effect of worm castings (WH) and naphthalencetic acid (ANA) on height (PH), stem diameter (SD), leaf greenness (FG), leaf number (LN), and leaf area index (LAI).) of plants of two zucchini cultivars under shaded housing conditions.

Treatment	AP (cm)	DT (mm)	VF (SPAD)	NH	IAF (m^2 m^{-2})
T1=Prestige+HL+ANA	92.1 b[§]	14.6 a	52.8 a	23.9 a	1.5 bc
T2=Prestige+HL	91.9 b	15.0 a	52.7 a	24.4 a	2.0 ab
T3=Prestige+ANA	91.9 b	14.8 a	54.4 a	24.3 a	1.8 ab
T4=Prestige	93.1 b	14.7 a	52.2 a	26.3 a	2.4 a
T5=HMX58+HL+ANA	139.0 a	13.4 a	49.8 a	22.7 a	1.5 bc
T6=HMX58+HL	147.8 a	13.8 a	50.6 a	26.0 a	2.0 ab
T7=HMX58+ANA	143.3 a	13.6 a	50.1 a	25.1 a	1.1 c
T8=HMX58	136.5 a	14.0 a	52.1 a	24.1 a	1.7 bc
DMSH	20.6	2.8	7.3	4.7	0.6
Significance					
CULTIVATE	***	*	*	ns	**
HL	ns	ns	ns	ns	ns
ANA	ns	ns	ns	ns	***
CULTIVATE×HL	ns	ns	ns	ns	**
CULTIVATE×ANA	ns	ns	ns	ns	ns
HL×ANA	ns	ns	ns	ns	ns

[§] Means with equal letters are not statistically different (Tukey≤0.05). DMSH=honest least significant difference; ns, *, **, ***: not significant at p≤0.05, significant at p≤0.05, p≤0.01 y p≤0.001.

The leaf dry weight was significantly influenced by the cultivar and naphthaleneacetic acid factors, as well as the interaction of these (Table 3). The Prestige cultivar plants exceeded the dry weight of leaves of the HMX58 cultivar plants by 51.6%. The highest dry weight of leaves was obtained in the Prestige treatment, without differences with the Prestige+WH, but higher than 53.3 (Prestige+ANA) to 115.2% (HMX58+ANA) than the dry weight of leaves induced by the rest of the treatments. Also, due to the naphthaleneacetic acid application, the leaves dry weight decreased. The cultivar factor affected the stem dry weight since this variable of the HMX58 cultivar exceeded that of the Prestige cultivar by 22.1% (Table 3). The highest stem dry weight was obtained with HMX58+LC, which exceeded that produced by Prestige+ANA and Prestige+WH+ANA by 49.6 and 51.2%, but with no differences with the effect of the rest of the treatments.

The cultivar and naphthaleneacetic acid factors affected the plant's dry weight; since, the Prestige cultivar exceeded that variable by 17.7% compared to the HMX58 cultivar, and with the naphthaleneacetic acid application the dry weight per plant decreased by 14.5%. (Table 3). Thus, the Prestige treatment plants had the highest dry weight, although it only exceeded that obtained in the HMX58+ANA, HMX58, and HMX58+WH+ANA treatments, by 31.5 to 39.1%.

Table 3. Effect of worm castings (WH) and naphthaleneacetic acid (ANA) on leaves dry (LDW), stem (SDW), and whole plant (PDW) weight of two zucchini cultivars under shaded housing conditions.

Treatment	PSH (g)	PST (g)	PSP (g)
T1=Prestige+HL+ANA	132.6 bc[§]	45.7 b	364.7 abc
T2=Prestige+HL	175.0 ab	51.1 ab	438.6 ab
T3=Prestige+ANA	135.2 bc	46.2 b	367.1 abc
T4=Prestige	207.2 a	56.3 ab	450.0 a
T5=HMX58+HL+ANA	99.2 c	63.0 ab	342.0 bc
T6=HMX58+HL	130.3 bc	69.1 a	387.1 abc
T7=HMX58+ANA	96.8 c	57.5 ab	323.5 c
T8=HMX58	102.5 c	53.9 ab	324.1 c
DMSH	59.2	21.3	108.4
Significance			
CULTIVATE	***	**	***
HL	ns	ns	ns
ANA	***	ns	**
CULTIVATE×HL	ns	ns	ns
CULTIVATE×ANA	*	ns	ns
HL×ANA	ns	ns	ns

[§] Means with equal letters are not statistically different (Tukey≤0.05). DMSH=honest least significant difference; ns, *, **, ***: not significant at p≤0.05, significant at p≤0.05, p≤0.01 y p≤0.001.

The observed differences in dry weight production coincide with the morpho-physiological variation between zucchini cultivars reported by Loy (2004). Furthermore, the dominant force on the photosynthates demand exerted by the fruits, related to the production capacity assimilated by the plant, can also regulate vegetative development (Loy, 2004; Sedano-Castro *et al.*, 2005; Luna *et al.*, 2015; Orozco *et al.*, 2016). This explains the greater dry weight in the Prestige cultivar plants, compared to those from the HMX58 cultivar, which developed more fruits per plant (Table 4).

The fruit set was affected by the cultivar and worm castings factors since the plants of the Prestige cultivar exceeded the fruit set of HMX58 by 34.8%, with the vermicompost application, this increased by 22.6%. The interaction between cultivar and worm castings, cultivar and naphthaleneacetic acid, or worm castings and naphthaleneacetic acid also influenced this variable (Table 4). A higher percentage of fruit set was obtained with the Prestige+WH treatment, which exceeded that achieved with HMX58+ANA, HMX58, and HMX58+WH+ANA, from 42.3 to 199.6%. The fruit set percentage obtained with pumpkin plants managed without pollination (24.8 to 68.3%), concurs with the 38 to 82% reported by Robinson and Reiners (1999), who point out that some cultivars' ability to produce fruits without pollination is fortuitous because they were not selected for that characteristic. They also agree with Kurtar (2003), who obtained the highest fruit set percentages in "green zucchini" type cultivars compared to other types of zucchini. Overall, the obtained fruit setting result is close to the 49.3% fruit setting reported by Pagoto *et al.* (2020) with 'Antonella' zucchini and is also in the range of 59.5 to 77.9% fruit set of 'Obsession' zucchini reported by Ayala-Tafoya *et al.* (2020), or the 56% fruit set of 'Tosca' squash without pollination described by Knapp and Osborne (2017).

The increase in fruit set achieved with the application of worm castings shows that its soil application as a source of natural growth-promoting substances (Fritz *et al.*, 2012; Calvo *et al.*, 2014; Aremu *et al.*, 2015), can be useful to increase the concentrations of endogenous phytohormones and promote zucchini fruit's growth (Li *et al.*, 2002; 2005), in the absence of pollinating insects.

The cultivar, worm castings, and naphthaleneacetic acid factors, and the interaction between worm castings and naphthaleneacetic acid influenced the number of fruits produced per plant (Table 4). The HMX58 cultivar produced 15.1% more fruits than the Prestige cultivar, while worm castings application increased this variable by 10.7%. The HMX58+WH treatment induced the highest fruits per plant number, with no difference with the Prestige+WH response, which exceeded that induced by the rest of the treatments, from 18.4 (HMX58) to 55.6% (Prestige+WH+ANA). The number of fruits per plant is similar to research by Rodríguez-Dimas *et al.* (2007) and Ayala-Tafoya *et al.* (2020), who report an increased number of fruits per plant as a consequence of soil application of worm castings; from this practice, Mogollón *et al.* (2014) report increases in enzymatic activity and edaphic respiration.

The monoesy of cucurbit plants requires the interaction with pollinating insects to achieve fruit set and production (Vidal *et al.*, 2010; Petersen *et al.*, 2013), or performing manual pollination to optimize the fruiting under conditions of mesh housing when bees or bumblebees are not available (Román-Román *et al.*, 2022). However, Ayala-Tafoya *et* *al.* (2020) report that vermicompost application in zucchini cultivation induced fruit set. Additionally, applications of organic fertilizer also promote an increase in the diameter, length, and weight of fruit variables (Rodríguez-Dimas *et al.*, 2007; Ayala-Tafoya *et al.*, 2020).

Fruit diameter was significantly influenced by all the main analyzed factors and interactions (Table 4). The HMX58 cultivar reported a fruit diameter 15.7% larger than that observed in the Prestige cultivar. The worm castings and naphthaleneacetic acid application increased it by 6.4 and 9.9%, respectively. Therefore, the HMX58+WH, HMX58+ANA, and HMX58+WH+ANA treatments induced a fruit diameter that exceeded the effect of the other treatments, from 9.5 (Prestige+ANA) to 38.9% (Prestige).

All factors and interactions also influenced the fruit length variable, except for the cultivar and worm castings interaction (Table 4). However, contrary to the fruit diameter, a 30.9% greater fruit length was recorded in the Prestige cultivar compared to the HMX58. Likewise, with the worm castings and naphthaleneacetic acid application, fruit length increased by 6.1 and 10.7%, respectively. The Prestige+ANA and Prestige+WH+ANA treatments had a fruit length that exceeded the effect caused by the other treatments, between 9 (Prestige+LC) to 56.7% (HMX58).

Fruit weight was favored by the worm castings and naphthaleneacetic acid factors, and by the cultivar and naphthaleneacetic acid, and between worm castings and naphthaleneacetic acid interactions (Table 4). The application of worm castings also

Table 4. Effect of worm castings (WH) and naphthaleneacetic acid (ANA) on fruit set (FS), number (NF), diameter (FD), length (FL), and fruit weight (FW) of two zucchini cultivars under shaded housing conditions.

Tratamiento	CF (%)	NF	DF (mm)	LF (mm)	PF (g)
T1=Prestige+HL+ANA	52.1 ab[§]	26.8 e	37.9 bc	187.4 a	202.6 a
T2=Prestige+HL	68.3 a	36.1 ab	35.2 cd	171.9 b	158.9 bc
T3=Prestige+ANA	58.2 ab	28.4 de	38.8 b	189.0 a	213.0 a
T4=Prestige	57.8 ab	30.2 cde	31.9 d	154.8 c	120.6 c
T5=HMX58+HL+ANA	48.0 b	32.7 bcd	42.5 a	137.8 d	189.0 ab
T6=HMX58+HL	58.4 ab	41.7 a	44.3 a	141.3 cd	195.1 ab
T7=HMX58+ANA	44.2 b	30.2 cde	43.2 a	137.5 d	197.1 ab
T8=HMX58	24.8 c	35.2 bc	36.4 bc	120.6 e	119.7 c
DMSH	15.2	5.4	3.2	13.1	37.1
Significance					
CULTIVATE	***	***	***	***	ns
HL	***	***	***	***	***
ANA	ns	***	***	***	***
CULTIVATE×HL	**	ns	*	ns	ns
CULTIVATE×ANA	*	ns	*	***	*
HL×ANA	***	**	***	***	***

[§] Means with equal letters are not statistically different (Tukey≤0.05). DMSH=honest least significant difference; ns, *, **, ***: not significant at p≤0.05, significant at p≤0.05, p≤0.01 y p≤0.001.

promoted an increase in the fruit weight by 14.6%, naphthaleneacetic acid increased it by 34.9%. The highest fruit weight was recorded in the Prestige+ANA and Prestige+WH+ANA treatments, whose average weight exceeded 68 to 77.9% obtained in the Prestige+WH, Prestige, and HMX58 treatments; but, with no differences with the other treatments' effects.

ANA treatments promoted increasing fruit diameter, length, and weight in both cultivars. Auxins promote cell enlargement, as a consequence of the plasticity of cell walls increase (Jankiewics and Acosta-Zamudio, 2003; Ayala-Tafoya *et al.*, 2012), and because the tissues where auxins have a sufficiently high concentration become an attraction point for nutrients and other hormonal substances such as gibberellins (Jankiewics and Acosta-Zamudio, 2003).

The cultivar and worm castings factors, and the interactions between cultivar and worm castings, worm castings, and naphthaleneacetic acid, had a significant effect on the yield (Table 5). The HMX58 cultivar produced 54.2% more yield than the Prestige cultivar, while with vermicompost it increased by 31.3%, compared to the non-application of organic fertilizer. The highest yield was obtained with the HMX58+WH treatment, which exceeded the yield achieved with the rest of the treatments, from 38.1 (HMX58+WH+ANA) to 183.2% (Prestige).

The yield with cultivar HMX58 and with the HMX58+WH treatment is similar to that reported by Román-Román *et al.* (2022) for the same cultivar, with (79.7 t ha^{-1})

Table 5. Effect of worm castings (WH) and naphthaleneacetic acid (ANA) on commercial yield and lagging fruits of two zucchini cultivars under shade housing conditions.

Treatment	CF (%)	DF (mm)	LF (mm)	PF (g)	Yield (t ha^{-1})
T1=Prestige+HL+ANA	52.1 ab[§]	37.9 bc	187.4 a	202.6 a	36.0 cd[§]
T2=Prestige+HL	68.3 a	35.2 cd	171.9 b	158.9 bc	50.0 bc
T3=Prestige+ANA	58.2 ab	38.8 b	189.0 a	213.0 a	44.4 bcd
T4=Prestige	57.8 ab	31.9 d	154.8 c	120.6 c	29.7 d
T5=HMX58+HL+ANA	48.0 b	42.5 a	137.8 d	189.0 ab	60.9 b
T6=HMX58+HL	58.4 ab	44.3 a	141.3 cd	195.1 ab	84.1 a
T7=HMX58+ANA	44.2 b	43.2 a	137.5 d	197.1 ab	60.6 b
T8=HMX58	24.8 c	36.4 bc	120.6 e	119.7 c	41.3 cd
DMSH	15.2	3.2	13.1	37.1	16.1
Significance					
CULTIVATE	***	***	***	ns	***
HL	***	***	***	***	***
ANA	ns	***	***	***	ns
CULTIVATE×HL	**	*	ns	ns	**
CULTIVATE×ANA	*	*	***	*	ns
HL×ANA	***	***	***	***	***

[§] Means with equal letters are not statistically different (Tukey≤0.05). DMSH honest least significant difference; ns, *, **, ***: not significant at p≤0.05, significant at p≤0.05, p≤0.01 y p≤0.001.

and without manual pollination (56.7 t ha^{-1}). This indicates that besides the natural parthenocarpy level of the cultivar, the yield was favored by the soil worm castings application, since this, in addition to increasing nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, and microelements availability (Olivares-Campos *et al.*, 2012), provides active substances with phytohormonal effects (Domínguez *et al.*, 2010; Calvo *et al.*, 2014; Aremu *et al.*, 2015). These promote fruit growth (Rodríguez-Dimas *et al.*, 2007; Ayala-Tafoya *et al.*, 2020), and induce increased performance (Reyes-Pérez *et al.*, 2017, Ayala-Tafoya *et al.*, 2020).

Ayala-Tafoya *et al.* (2020) discuss that auxins: 1-naphthaleneacetic acid (0.45%)+1-naphthaleneacetamide (1.2%) increased the fruit set percentage, number of fruits per plant, and yield in zucchini. In this case, naphthaleneacetic acid (ANA), even when not improving the fruit set and number of fruits per plant, did promote zucchini yield by increasing the diameter, length, and weight of their fruits. Montaño and Méndez (2009) and Ariza *et al.* (2015) mention that the naphthaleneacetic acid effect has been detrimental to some crop's yield.

CONCLUSIONS

Applying worm castings increases zucchini yield, fruit set percentage, and number of fruits per plant. Due to the naphthaleneacetic acid effect, the diameter, length, and weight of the fruit increased. The treatments did not influence the stem diameter, leaf greenness, and number of leaves variables; In the Prestige cultivar, a higher leaf area index, the dry weight of leaves and whole plant was obtained; while, with the HMX58 cultivar, greater plant height was achieved.

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