Fine-tuning nutrient electrical conductivity in substrate hydroponics to boost growth and early fruit set of melon in a smart greenhouse

Tri Rini Kusparwanti[1*], *Rindha Rentina Darah* Pertami[1†], *Suwardi* Suwardi[1], *Fadil* Rohman[1], *Suwinda* Fibriani[2], *Aulia Aviqorina* Fathi[1]

[1]Departement of Agricultural Production, Politeknik Negeri Jember, Mastrip Street PO BOX 164 Jember East Java, Indonesia

[2]Departement of Management Agriculture, Politeknik Negeri Jember, Mastrip Street PO BOX 164 Jember East Java, Indonesia

Abstract. Hydroponic melon (Cucumis melo L.) production is constrained by the high cost of standard standard AB Mix nutrients. This study evaluated an economical alternative (½ AB Mix + ½ Gandasil) at varied Electrical Conductivity (EC) levels (3, 4, 5 mS/cm) against a standard control (100% AB Mix, EC 3) within a Smart Green House (SGH). The experiment revealed a significant paradox while high-concentration treatments (C1EC5 and C0EC3) acted as potent stimulants, significantly accelerating early vegetative growth and initial fruit set, this advantage was completely nullified by the final harvest. Analysis of variance (ANOVA) confirmed no significant difference (ns) across any critical yield parameters, including fruit weight, diameter, and sweetness (°Brix). The data demonstrates that a non-nutritional, overriding limiting factor suppressed the crop's potential. Supra-optimal thermal stress, with ambient SGH temperatures averaging 32°C, impaired photosynthetic efficiency and assimilate translocation. We conclude that in this system, meticulous environmental temperature control is an indispensable prerequisite that must take precedence over optimizing nutrient concentration to achieve viable yields.

1 Introduction

Melon (*Cucumis melo* L.) is a horticultural fruit commodity highly valued for its significant economic worth in the domestic market. The popularity of this commodity is driven by its superior attributes, such as sweet taste quality, crisp texture, and high nutritional content [1-4]. Melon fruit is rich in water, protein, fat, carbohydrates, fiber, and essential minerals, and contains 357 IU of Vitamin A per 100 grams of edible weight [5-7]. This growth in consumption necessitates a stable and high-quality supply. However, this rising demand faces the reality of national production, which is tending to decline and fluctuate. The national production rate of the melon commodity reached 138,177 tons in 2020, but this figure

* Corresponding author: tri_rini@polije.ac.id

progressively decreased to 118,711 tons in 2022. This repeated production decline is attributed to two main factors: environmental pressure from extreme climate, and agronomic challenges related to inefficient nutrient absorption by plants [8-10]. The limited availability of agricultural land further exacerbates the challenges of conventional cultivation. This condition collectively increases price volatility and compels the adoption of more controlled, efficient, and resilient cultivation methods against climate change to ensure the stability and quantity of harvests.

Hydroponic melon cultivation in a Smart Green House (SGH) using a cocopeat substrate presents a modern solution to agricultural limitations, promising enhanced crop quality and value [10-12]. This controlled environment allows for precision management of the microclimate, plant health, and nutrient delivery. However, a significant challenge identified in this research was a supra-optimal ambient temperature, averaging 32°C, which exceeds the ideal range for melons (25-30°C). This thermal stress is a critical factor, as it can impede the translocation of assimilates (sugars) to the fruit and ultimately suppress the final yield, highlighting a key limitation for precision agriculture in this context. In hydroponics, fertigation, the precise delivery of dissolved nutrients, is the most critical factor. The standard solution, AB Mix, provides all essential macro (Solution A) and micro (Solution B) elements for plant growth [13-16]. However, the high price of AB Mix significantly increases production costs [17-19]. This economic pressure creates a need for more economic nutrient formulations. This study addresses this by testing a combination strategy: using ½ AB Mix combined with ½ Gandasil (B or D), an affordable inorganic foliar fertilizer, as a macro and micronutrient supplement.

Based on the background and the urgency of optimizing an efficient and effective nutrient formula in the hydroponic system, this research addresses two main problems as the focus of investigation (1) how does the combination of AB MIX + Gandasil with varying EC levels, affect the growth and yield of melon plants? And (2) what is the best EC level that can provide the optimal growth and production yield of melon plants? This study tests how different strengths (EC) of an AB MIX + Gandasil fertilizer affect melon growth, aiming to find the best strength to produce the most melons. Achieving these objectives requires observation of vegetative parameters (plant height, number of leaves), generative parameters (number of female flowers, number of flowers that become fruit), and final yield parameters (fruit weight, diameter, sweetness level, and flesh/skin thickness), followed by comprehensive statistical analysis.

2 Materials and Methods

2.1 Research Design

The methodology employed in this study was systematically designed to evaluate the effect of combining AB Mix and Gandasil nutrients at various the ability of a material to conduct electric current called Electrical Conductivity (EC) concentration levels on the growth and production yield of melon plants (*Cucumis melo* L.) using the substrate hydroponic system within a controlled environment. The research was conducted from June to September 2025 at the Smart Green House (SGH) located on the East side of Politeknik Negeri Jember, East Java, at an elevation of approximately ± 89 meters above sea level. The study utilized a Completely Randomized Design (CRD) with one factor, which was the difference in special nutrient solution for hydroponic plants which consists of a mixture of two types of fertilizer, namely fertilizer A and fertilizer B, which contain complete macro and micro nutrients for plant growth (AB mix) solution concentration (½ AB Mix + ½ Gandasil B and Gandasil D). The experiment involved four treatments, replicated 6 times, resulting in a total of 24 experimental units. Each experimental unit contained 3 sample plants, totaling 72 plants under observation. The collected data were subjected to analysis using the Least Significant Difference (LSD) test at 1% and 5% significance levels. The four treatments tested were defined as:

C_0EC_3: Control (100% AB Mix) and 3 EC as Standard Control (Without Gandasil)
C_1EC_3: 1/2 AB Mix + 1/2 Gandasil (B/D) and 3 EC as Nutrient Combination, Efficient EC
C_1EC_4: 1/2 AB Mix + 1/2 Gandasil (B/D) and 4 EC as Nutrient Combination, Medium EC
C_1EC_5: 1/2 AB Mix + 1/2 Gandasil (B/D) and 5 EC as Nutrient Combination, High EC

2.2 Media Preparation

Cocopeat was placed into 20×40 cm polybags. The media was saturated with water until the outflowing water was no longer red. This process aimed to remove toxic tannin substances that could inhibit growth [20, 21]. Hybrid melon seeds of the Sweet Hammi variety were used. Seeds were soaked for 6 – 8 hours in water (with crushed shallots to aid imbibition), then arranged on a tissue-lined container. After germination, the seeds were moved to trays filled with cocopeat until 14 Days After Sowing (DAS). Seedlings were transplanted into the polybags in the afternoon when they reached 14 DAS (marked by the appearance of 1 – 2 true leaves).

2.3 Experimental Design

This combined watering and fertilization process was applied from transplanting until harvest, using a manual drip system with a volume of 250 ml of nutrient solution per plant per watering. The nutrient solution concentration (EC) was measured using an EC meter according to the respective treatments. Observation Parameters Measurements were taken periodically for vegetative, generative, and final yield parameters, including Vegetative Phase (Plant Height (cm) and Number of Leaves (sheets), measured weekly) and Generative Phase (Number of female flowers (on branches 8 – 20) and Number of female flowers that become fruit), also Final Yield Parameters: Fruit Weight (gr), Fruit Diameter (mm), Sweetness Level (Brix using a Refractometer), Fruit Flesh Thickness (mm), and Fruit Skin Thickness (mm).

3 Results and Discussion

The statistical analysis using the F-Test (ANOVA) was applied to evaluate the effect of the nutritional combination intervention (½ AB Mix + ½ Gandasil B/D) at different Electrical Conductivity (EC) levels on the growth parameters and yield production of hydroponic melon plants. The recapitulation of the analysis of variance is presented in table 1.

Table 1. Recapitulation of F-Test on Melon Growth and Yield Parameters

Observation Parameter	F-test	Observation Parameter	F-test
Plant height 1 WAT	1.40ns	Number of leaves 6 WAT	01.08ns
Plant height 2 WAT	0.66ns	Number of leaves 7 WAT	1.59ns
Plant height 3 WAT	1.86ns	Number of female flowers 4 WAT	3.78*
Plant height 4 WAT	3.57*	Number of female flowers 5 WAT	0.91ns
Plant height 5 WAT	3.98*	Number of fruit-setting female flowers 5 WAT	9.70**
Plant height 6 WAT	3.84*	Number of fruit-setting female flowers 6 WAT	1.45ns
Plant height 7 WAT	4.35*	Fruit weight per sample plant	0.18ns
Number of leaves 1 WAT	1.51ns	Fruit skin thickness per sample plant	0.65ns
Number of leaves 2 WAT	2.46ns	Fruit flesh thickness per sample plant	1.78ns

Observation Parameter	F-test	Observation Parameter	F-test
Number of leaves 3 WAT	3.99*	Fruit diameter per sample plant	0.19ns
Number of leaves 4 WAT	11.53*	Sweetness level (Brix) per sample plant	0.07ns
Number of leaves 5 WAT	3.56*		

Note: ns: non-significant, *: Significant, **: Highly Significant, WAT: Weeks After Transplanting.

The F-test results indicate significant differences during the vegetative and early generative phases. Specifically, the treatments showed a highly significant effect on the number of leaves at 4 WAT and the number of fruit-setting female flowers at 5 WAT. A significant effect was observed for plant height (4 to 7 WAT), number of leaves (3 and 5 WAT), and number of female flowers (4 WAT). Importantly, all final yield parameters (fruit weight, fruit diameter, sweetness level, flesh and skin thickness) exhibited a non-significant effect (Ns) among treatments. The analysis of vertical plant growth reveals that nutrient treatments began to exert a significant effect from 4 WAT through 7 WAT. During this period, the average plant height for treatment C_0EC_3 and C_1EC_5 was statistically superior compared to C_1EC_3 and C_1EC_4 (Table 2). Absolutely, C_0EC_3 achieved the highest average height (258.75 cm) at the end of the observation period.

Table 2. The number of leaves

Treatment	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	7 WAT
C_0EC_3	9.74	21.72	59.72	134.17a	206.22a	250.39a	258.75a
C_1EC_3	10.94	21.00	49.50	108.56b	152.00b	187.61b	197.86b
C_1EC_4	12.24	25.09	56.28	107.22b	137.17b	184.97b	210.22ab
C_1EC_5	12.51	27.10	69.17	131.67a	168.86ab	199.39a	208.11ab

Table 3. Average Number of Melon Leaves (Sheets)

Treatment	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	7 WAT
C_0EC_3	1.83	4.11	9.50b	22.39b	26.44b	28.50	30.14
C_1EC_3	2.44	5.22	10.00b	17.17b	23.56b	26.04	27.72
C_1EC_4	2.17	4.84	9.83b	16.17b	21.44b	26.28	27.22
C_1EC_5	2.72	6.28	12.50a	19.55a	25.95a	27.92	29.45

The number of leaves is a vital indicator of vegetative vigor and photosynthetic capacity. Observations indicated a very rapid response, showing a significant effect at 3 and 5 WAT, and a highly significant effect at 4 WAT. Treatment C_1EC_5 (EC 5 mS/cm) consistently recorded the highest average number of leaves (Table 3), with a significant difference at 4 WAT (19.55 sheets) compared to C_1EC_3 and C_1EC_4. This confirms that higher nutrient concentration (EC 5 mS/cm) is effective in stimulating early vegetative growth. In the early generative phase (4 WAT), treatments exhibited a significant effect on the number of female flowers. Control (C_0EC_3) produced the highest number of female flowers at 4 WAT (4.22 flowers), followed by C_1EC_5 (2.83 flowers) (Table 4). Furthermore, fruit initiation at 5 WAT showed a highly significant effect among treatments. Treatment Control recorded the highest number of flowers successfully setting fruit (4.17 fruits), followed by C_1EC_5 (2.00 fruits) (Table 4). These data indicate the superior efficacy of pure AB Mix nutrition (C_0EC_3) and the potential of the combined formula at the highest nutrient concentration (C_1EC_5) in supporting the transition from the flowering to the fruiting phase, compared to lower nutrient concentrations (C_1EC_3 and C_1EC_4).

Table 4. Average Number of Female Melon Flowers (Flowers) and Average Number of Fruit-Setting Female Flowers (Fruits)

Treatment	Average number of female melon flowers		Average number of fruit-setting female flowers	
	4 WAT	5 WAT	5 WAT	6 WAT
C_0EC_3	4.22a	06.03	4.17a	5.89
C_1EC_3	2.39b	04.09	1.17bc	2.59
C_1EC_4	2.39b	4.22	0.58c	1.5
C_1EC_5	2.83b	4.99	2.00b	4.03

Statistical analysis confirms that despite significant differences in vegetative parameters (plant height and number of leaves) and initial fruit setting, the differences in EC level and nutrient formulation did not exert a significant effect on any of the final harvest quality and quantity parameters (Table The ability of a material to conduct electric current.The ability of a material to conduct electric current.The ability of a material to conduct electric current.The ability of a material to conduct electric current.The ability of a material to conduct electric current.1). These parameters include Fruit Weight, Fruit Diameter, Sweetness Level (°Brix), Fruit Flesh Thickness, and Fruit Skin Thickness. In terms of absolute average data (Table 5), Treatment control produced the highest fruit weight (713.67 gr) and the largest fruit diameter (101.83 mm), but the highest sweetness level was achieved by C_1EC_3 (EC 3 mS/cm combination) at 14.50 °Brix. However, because all these differences were statistically non-significant, the conclusion drawn is that the nutrient variations tested did not produce statistically distinguishable differences in final yield results.

Table 5. Average Fruit Weight, Diameter, and Sweetness Level

Treatment	Fruit Weight (gr)	Fruit Diameter (mm)	Fruit Sweetness Level (°Brix)
C_0EC_3	713.67	101.83	12.67
C_1EC_3	507.37	96.83	14.50
C_1EC_4	503.5	93.23	12.33
C_1EC_5	399.63	86.70	12.67

The results of the analysis indicate a contradiction between the initial growth phase and the final yield phase. Treatments with high EC C_0EC_3 and C_1EC_5 proved significantly superior in stimulating vegetative growth (plant height and number of leaves) and early fruit initiation (number of fruit-setting female flowers). This achievement of of Ariessandy, *et al* (2022) and Laksono (2017) aligns with the findings of EC [20,21], who stated that EC 5 mS/cm is the optimal level for melon growth, and that higher EC levels can enhance optimal plant growth if appropriate for the plant's needs [22-24]. The superiority of EC 5 mS/cm (C_1EC_5) on leaf number and EC 3 mS/cm on plant height and fruit set number indicates that adequate nutrient concentration is crucial for promoting biomass accumulation in the vegetative phase and generative transition. Despite the significant differences in the initial phase, the absence of a significant effect on final yield parameters (fruit weight and sweetness level) suggests that non-nutritional environmental factors may have been the primary limitation to the plant's genetic potential. Micro-environmental measurements in the Smart Green House (SGH) revealed significant temperature stress. The average daily temperature recorded reached 32 °C, with the maximum temperature reaching 32.4 °C. This temperature is above the ideal range required for optimal melon plant growth, which is 25 − 30 °C [27]. This high temperature is strongly suspected to inhibit the translocation of assimilates (sugars) from the leaves to the fruit, which should occur during the fruit-filling phase. Research by Adinegara et al (2017) indicates that thermal stress conditions can reduce photosynthetic efficiency and sugar accumulation in the fruit area. This is consistent with the fruit sweetness levels obtained in this study (ranging from 12.33 to 14.50 °Brix), which are significantly lower than the Sweet Hammi variety description of 16 °Brix.

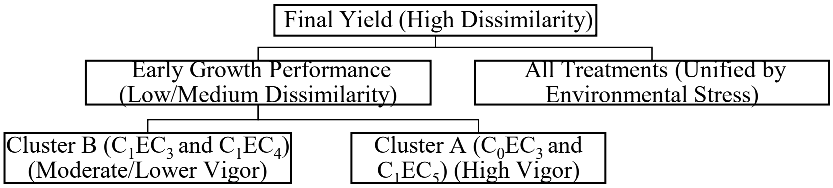

Fig. 1. Dendrogram analysis

At a lower level of dissimilarity (early growth phases), treatments C_0EC_3 and C_1EC_5 would cluster together due to their superior performance in height, leaf count, and fruit set. Similarly, C_1EC_3 and C_1EC_4 would cluster together, indicating their relatively lower performance in these early parameters. However, when considering the full spectrum of parameters, especially the final yield (which showed no significant differences), all treatments would merge into a single, overarching cluster at a much higher level of dissimilarity. This final convergence indicates that, despite initial differences induced by varying nutrient ECs, an external environmental factor (high temperature) ultimately constrained all treatments to a similar final yield outcome.

4 Conclusion

The experiment revealed a distinct paradox. While a high-concentration nutrient solution (EC 5 mS/cm) acted as a powerful stimulant, significantly accelerating early vegetative growth and fruit set, this initial advantage was completely nullified by the final harvest. Ultimately, all critical yield and quality parameters including Fruit Weight, Diameter, Sweetness, and Flesh Thickness were statistically identical across all treatment groups. This outcome is attributed to a prevailing limiting factor: severe thermal stress. The average greenhouse temperature (32°C) exceeded the melon's optimal range, impairing photosynthetic efficiency and the translocation of assimilates (sugars) to the fruit. The study decisively concludes that in this system, meticulous environmental temperature control is an indispensable prerequisite that must take precedence over optimizing nutrient concentration for achieving final yields.

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