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Vegetative Response of Cocoa Seedlings (*Theobroma cacao* L.) to Nitrophenol Compound Concentration and NPK Fertilizer Dose

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Abstract

Cocoa is a vital plantation commodity in Indonesia, but its productivity is hindered by suboptimal seedling quality. This study aimed to evaluate the vegetative growth response of cocoa seedlings to various combinations of nitrophenol compound concentrations and NPK fertilizer doses, and to identify the optimal treatment combination. The experiment was conducted at the Experimental Garden of the Faculty of Agriculture, Pasir Pengaraian University, Riau, from June to October 2025, using a Randomized Complete Block Design (RCBD) with a factorial arrangement. The first factor was the concentration of nitrophenol compounds (0, 1.5, 3.0, and 4.5 ml/L), and the second factor was the NPK fertilizer dose (0, 5, and 10 g per polybag). The parameters measured included plant height, stem diameter, leaf number, root volume, and dry weight. Data were statistically analyzed using an F-test (ANOVA) at the 5% significance level with PKBT-STAT 3.2, followed by the Honestly Significant Difference (HSD) test at the 5% level. The results indicated a highly significant interaction ($P < 0.01$) between nitrophenol compounds and NPK fertilizer on all measured parameters. The combination of 4.5 ml/L nitrophenol compounds and 10 g/polybag NPK fertilizer produced the best results, with a plant height of 46.00 cm, 17 leaves, a stem diameter of 0.69 cm, a root volume of 6.50 ml, and a dry weight of 4.38 g. These findings demonstrate that increasing both the concentration of the nitrophenol compound and the fertilizer dose synergistically enhances the vigor and quality of cocoa seedlings.

Keywords: Atonik, Cocoa nursery, Forastero, Inceptisol, Plant growth regulators

1. Introduction

Cocoa (*Theobroma cacao* L.) is an important plantation commodity for Indonesia, serving as a source of foreign exchange, employment, and farmer income, and playing major role in the world export market (Kindangen et al., 2017; Yunindanova et al., 2021).

Indonesia's cocoa plantation sector is facing a complex dynamic between declining production volumes and surging global economic value. According to data from the Central Statistics Agency (BPS), national cocoa production reached 617,110 tons in 2024, a 2.37% decrease compared to 632,090 tons in 2023 (Badan Pusat Statistik, 2024).

Various factors, including aging cocoa plants, pest and disease attacks, climate change, and suboptimal cultivation practices, such as the use of low-quality seeds, can cause this decline in production.

Optimal vegetative growth of cocoa seedlings is an important prerequisite before transplanting seedlings to the field, because seedling quality is crucial for successful plantation development and long-term cocoa crop productivity (Ramadhani et al., 2024; Wati et al., 2021). Vegetative parameters such as plant height, leaf number, stem diameter, and root length/volume are commonly used as indicators of seedling vigor, which describe the seedling's ability to absorb water and nutrients, support the canopy, and form biomass that correlates with future plant adaptation and productivity (Falieza et al., 2022; Nasrullah et al., 2018; Wati et al., 2021).

One approach to improving the quality of cocoa seedlings is the use of plant growth regulators (PGRs) and

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balanced fertilization. Atonic PGRs are a group of nitrophenol compounds composed of sodium ortho-nitrophenol, sodium para-nitrophenol, sodium 5-nitroguaiacolate, and sodium 2,4-dinitrophenol. These compounds play a role in activating cell metabolism, increasing membrane permeability, accelerating nutrient absorption, and stimulating cell division and elongation. The use of nitrophenol compounds at optimum concentrations is expected to accelerate the vegetative growth of cocoa seedlings by optimizing plant physiological functions (Habeahan et al., 2021; Irawan et al., 2022).

Previous research has shown that the application of nitrophenol compounds, either through foliar methods or seed soaking, consistently increases vegetative growth parameters such as leaf number, fresh and dry weight (shoots and roots), leaf area, and chlorophyll content in various commodities. This observation has been identified in peas (Zrar, 2021), tomatoes (Tavallali, 2025), forage grasses (Liu, 2025), oilseed rape (Przybysz, 2014; Sikorska, 2022), and several other horticultural species. Application of nitrophenol compounds at 3 ml/L to cocoa seedlings significantly increased plant height, stem diameter, leaf number, and leaf area (Habeahan et al., 2021). Similar success was also found in robusta coffee, where application of 0.9 mL/L sodium nitrophenol resulted in a rooted cutting percentage of up to 65% (Nengsih, 2023).

In addition to nitrophenol compounds, nutrient availability through fertilization also plays an important role in supporting the vegetative growth of cocoa seedlings. NPK fertilizer is a compound fertilizer that provides the essential macronutrients nitrogen, phosphorus, and potassium in a composition suitable for the vegetative phase; nitrogen supports the formation of chlorophyll, structural proteins, and nucleic acids, phosphorus strengthens the root system and energy transfer, while potassium regulates cell osmotic pressure, activates enzymes, and increases plant tolerance to stress (Mintah et al., 2025; Sapitu et al., 2025).

The application of NPK fertilizer has consistently been shown to increase plant vigor through increased plant height, number of leaves, stem diameter, root volume, number of new shoots, and dry weight in various plants such as cocoa (Fatchurrohman et al., 2025; Hartawan et al., 2024; Sari & Alfrizon, 2023), olives (Rasheed, 2024), broccoli (Mohammed et al., 2024), and *Ervatamia coronaria* (Ashour et al., 2023). Although the effectiveness of each of these ingredients has been reported separately, studies on the response of cocoa seedlings (*Theobroma cacao* L.) to simultaneous exposure to nitrophenol concentrations with NPK fertilizer are still very limited. The fundamental difference between this study and previous research lies in the interaction between nitrophenol concentrations and macro fertilizer doses in stimulating vegetative growth and nutrient uptake efficiency during the seedling phase. Therefore, this combination approach is a key aspect of research novelty, aimed at optimizing technology to provide high-quality cocoa seedlings.

Based on the description above, research on the vegetative response of cocoa seedlings to varying concentrations of nitrophenol compounds and NPK fertilizer doses is highly relevant. The purpose of this study was to evaluate the vegetative growth response of cocoa seedlings to different combinations of nitrophenol concentrations and NPK fertilizer doses, and to identify the treatment combination that yields the best results.

2. Material and Methods

This research was conducted on marginal *Inceptisol soil* at the Experimental Garden of the Agrotechnology Study Program, Faculty of Agriculture, Pasir Pengaraian University (UPP) on Jalan Tuanku Tambusai, Kumu, Rambah Hilir Village, Rambah Hilir District, Rokan Hulu Regency, Riau. Geographically, this location is approximately at 0°54'47.1 N (North Latitude) and 100°19'43.4 E (East Longitude). This experimental garden is at an altitude of approximately 10-50 meters above sea level (masl). This research was conducted from June to October 2025.

The materials used in this study were Forastero variety cocoa seeds, nitrophenol compounds, NPK Grower fertilizer (15:9:20), *Inceptisol soil*, water, Decis 25 EC insecticide, and Dithane M-45 fungicide for pest and disease control. The tools used in this study included shade from a parasol (75% light intensity), polybags, hoes, machetes, sieves, hand sprayers, scissors, meters, callipers, measuring cups, rice paper envelopes, and stationery.

This study used a factorial Randomized Complete Block Design (RKLT). The first factor was the concentration of nitrophenol compounds, with 4 levels: 0 ml/L, 1.5 ml/L, 3.0 ml/L, and 4.5 ml/L. The second factor was the NPK fertilizer dose, with 3 levels: 0 g/polybag, 5 g/polybag, and 10 g/polybag. From these two factors, 12 treatment combinations were obtained as follows: concentration of nitrophenol compound 0 ml/L + dose of NPK fertilizer 0 g/ *polybag* , concentration of nitrophenol compound 0 ml/L + dose of NPK fertilizer 5 g/ *polybag*, concentration of nitrophenol compound 0 ml/L + dose of NPK fertilizer 10 g/ *polybag* , concentration of nitrophenol compound 1.5 ml/L + dose of NPK fertilizer 0 g/ *polybag*, concentration of nitrophenol compound 1.5 ml/L + dose of NPK fertilizer 5 g/ *polybag* , concentration of nitrophenol compound 1.5 ml/L + dose of NPK fertilizer 10 g/ *polybag*, concentration of nitrophenol compound 3.0 ml/L + dose of NPK fertilizer 0 g/ *polybag* , concentration of nitrophenol compound 3.0 ml/L + dose of NPK fertilizer 5 g/ *polybag*, concentration of nitrophenol compound 3.0 ml/L + dose of NPK fertilizer 10 g/ *polybag* , concentration of nitrophenol

compound 4.5 ml/L + NPK fertilizer dose 0 g/ *polybag*, concentration of nitrophenol compound 4.5 ml/L + dose of NPK fertilizer 5 g/ *polybag* , concentration of nitrophenol compound 4.5 ml/L + dose of NPK fertilizer 10 g/ *polybag* . Each treatment combination was repeated 4 times, yielding a total of 48 experimental units.

The observation data were analyzed statistically using the F-test (ANOVA) at the α = 5% level using PKBT-STAT 3.2 software (http://pbstat.com/pkbt-stat/). The F-test results showing a significant effect were further tested using the Honestly Significant Difference (HSD) test at the α = 5% level. The average standard error was calculated in Microsoft Excel. Implementation of this research presented in the following flowchart:

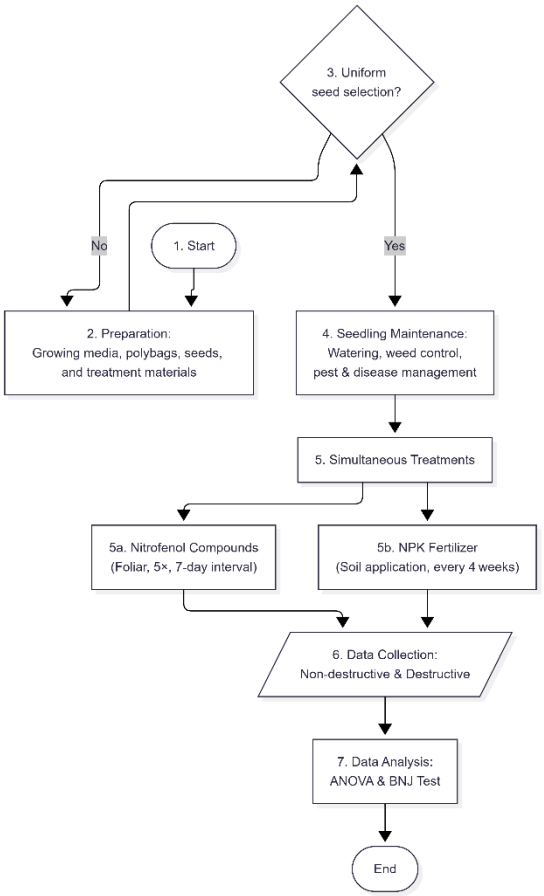

Figure 1. Research flow diagram

The research implementation includes several stages, namely (1) preparation of planting media and *polybags*, (2) sowing cocoa seeds, (3) selection of uniform seedlings to be used as research materials, and (4) application of nitrophenol compounds according to treatment concentrations. Nitrophenol compounds are applied to plants aged 3 weeks after planting (wap) by spraying the seedling leaves 5 times at 7-day intervals (Habeahan, 2021). (5) application of NPK fertilizer according to the treatment dose, which is carried out by circling the stem in the root zone and slightly immersing the plants aged 4 weeks after planting with an interval of 4 weeks, (6) seedling maintenance includes watering, weed control, and pest and disease control.

The variables observed in this study include plant height, stem diameter, leaf number, root volume, and plant dry weight. Plant height measurements were taken from the stem at ground level in *the polybag* to the tip of the plant, while stem diameter was taken at a height of 2 cm from the ground level in *the polybag* using a vernier caliper (Habeahan et al., 2021). Observations on the number of leaves were made when the leaves had fully opened. Root volume was measured by inserting the roots into a measuring cup filled with water. Plant dry weight was determined after plants were oven-dried at 80°C for 48 hours until constant weight (Rosniawaty et al., 2022).

3. Results and Discussion

The response of the administration of nitrophenol compound concentration and NPK fertilizer dose on the growth of cocoa seedling height (Table 1) had a significant effect at the 0.01 test level on plant height.

4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK treatment (Table 1) produced the highest plant height, at 46.00 cm, compared to the other treatments. These results indicate that the higher-dose combination provides optimal growing conditions for cocoa seedlings. This finding is consistent with research by Habeahan et al. (2021), which shows that administering higher concentrations of nitrophenol compounds increases plant height.

The increase in plant height in the treatment of 4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK shows that the administration of nitrophenol and NPK compounds can encourage plant physiological activity, especially in cell division and elongation. Nitrophenol compounds stimulate growth, while NPK fertilizer provides the macronutrients plants need to form vegetative tissue (Sari & Alfrizon, 2023).

Nitrogen plays a role in protein and chlorophyll formation; phosphorus supports energy transfer and root development; and potassium regulates enzyme activity and plant water balance. Several studies have shown that applying NPK fertilizer at the correct dosage increases seedling height, stem diameter, leaf area, root length, and cocoa seedling biomass in subsoil, Ultisol, and peat media (Nasrullah et al., 2018; Sari & Alfrizon, 2023).

The response to the administration of nitrophenol compound concentration and NPK fertilizer dose on the growth of cocoa seedlings (Table 2) had a significant effect at the 0.01 test level on the number of leaves.

The number of leaves in Table 2 of the 4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK treatment produced the highest value: 17.00 leaves. This indicates that sufficient nutrient availability and the presence of nitrophenol compounds can accelerate leaf formation. Nitrophenol compounds enhance fertilization effects by

stimulating cell division and elongation. Nitrophenol compounds in cocoa seedlings have been shown to increase the number of leaves (Habeahan et al., 2021; Nihad M. Abood & Shakir S. Mirare, 2024).

Table 1. Effect of nitrophenol compound concentration and NPK fertilizer on the height characteristics of cocoa seedlings at the age of 16 weeks after planting

Treatment	Plant Height (cm)
0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	24.38±1.28 g
0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	29.75±1.44 ef
0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	32.75±2.09 def
1.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	28.13±1.18 fg
1.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	33.75±0.75 cde
1.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	38.13±1.21 bc
3.0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	29.88±0.92 ef
3.0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	37.75±1.01 bcd
3.0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	40.75±0.75 b
4.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	33.25±1.09 cde
4.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	40.63±0.66 b
4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	46.00±2.02 a
F-test	**

** = has a significant effect at the 0.01 test level; numbers followed by the same letter in the same column are not significantly different based on the BNJ test at the α = 5% level.

Table 2. Effect of nitrophenol compound concentration and NPK fertilizer on the number of cocoa seedling leaves at the age of 16 weeks after planting.

Treatment	Number of leaves (blades)
0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	10.50±0.29 g
0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	12.00±0.00 f
0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	12.25±0.25 f
1.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	12.00±0.41 f
1.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	13.00±0.00 ef
1.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	14.25±0.48 cde
3.0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	13.00±0.00 ef
3.0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	14.75±0.25 bcd
3.0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	15.50±0.29 bc
4.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	13.75±0.25 de
4.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	15.75±0.25 ab
4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	17.00±0.00 a
F-test	**

** = has a significant effect at the 0.01 test level; numbers followed by the same letter in the same column are not significantly different based on the BNJ test at the α = 5% level.

More leaves increase the plant's photosynthetic capacity, producing more photosynthates to support the growth of other vegetative parts. (Arum et al., 2023; Mintah et al., 2025; Odoemelam et al., 2023)Thus, an increase in the number of leaves indicates that cocoa seedlings are in better growth conditions.

The administration of nitrophenol compound concentration and NPK fertilizer dose to cocoa seedlings (Table 3) had a significant effect at the 0.05 test level on the stem diameter of cocoa seedlings.

Table 3 shows the highest stem diameter value in the treatment of 4.5 ml/L nitrophenol compound + 10 g polybag NPK, namely 0.69 cm. Larger stem diameter reflects more robust growth and the plant's ability to support the vegetative organs above it. Adequate nutrient provision from NPK supports the formation of vascular tissue and stem thickening, while nitrophenol compounds accelerate cell growth. Seedlings with larger stem diameters generally exhibit greater vigour and higher survival rates after transplanting (Nasrullah et al., 2018; Ramadhani et al., 2024; Sari & Alfrizon, 2023).

Based on the results of the analysis of variance (Table 4), the interaction between the concentration of nitrophenol compounds and the dose of NPK fertilizer had a very significant effect (0.01 level) on the root volume of cocoa seedlings at the age of 16 weeks after planting. This finding indicates that these two factors act synergistically to stimulate root growth in cocoa seedlings. The data in Table 4 show a tendency: the higher the concentration of nitrophenol compounds and the higher the NPK dose, the greater the resulting root volume.

The treatment of 4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK Table 4 (the highest level of nitrophenol compound and the highest level of NPK) produced the

largest root volume, namely 6.50 ml, which was significantly different from the treatment of 0 ml/L nitrophenol compound + 0 g/ *polybag* NPK, which was only 2.50 ml. The optimal dose for stimulating root growth of cocoa seedlings up to 16 weeks after planting (WAP) is a combination of 4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK. The large root volume (6.50 ml) at a plant height of 46 cm (Table 1) ensures that seedlings have a strong anchorage system and a high nutrient-absorption capacity before being transferred to the field (*main nursery* or permanent land).

Root volume and dry weight reflect the ability of seedlings to absorb water and nutrients as well as the results of photosynthate accumulation, so they are directly related to the vigor and quality of cocoa seedlings and other plants (Arum et al., 2023; Lubis et al., 2020).

The results of the analysis of variance (Table 5) show that the concentration of nitrophenol compounds and the dose of NPK fertilizer have a significant effect at the 0.01 test level on the dry weight of cocoa seedlings. This indicates that the treatment not only stimulates physical growth (plant height) but also increases the accumulation of organic compounds in plant tissue.

Table 3. Growth in stem diameter of cocoa seedlings given nitrophenol compound concentration and NPK fertilizer dose at the age of 16 weeks after planting.

Treatment	Stem Diameter (cm)
0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	0.60±0.05 ab
0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	0.63±0.05 ab
0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	0.60±0.04 ab
1.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	0.63±0.04 ab
1.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	0.66±0.04 ab
1.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	0.65±0.03 ab
3.0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	0.63±0.05 ab
3.0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	0.59±0.03 b
3.0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	0.64±0.03 ab
4.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	0.63±0.02 ab
4.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	0.64±0.02 ab
4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	0.69±0.03 a
F-test	*

* = has a significant effect at the 0.05 test level; numbers followed by the same letter in the same column are not significantly different based on the BNJ test at the α = 5% level.

Table 4. Growth of cocoa seedling root volume given nitrophenol compound concentration and NPK fertilizer dose at 16 weeks after planting.

Treatment	Root Volume (ml)
0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	2.50±0.20 e
0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	2.73±0.32 de
0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	3.13±0.31 de
1.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	3.25±0.43 de
1.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	3.43±0.55 de
1.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	3.80±0.58 cde
3.0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	3.75±0.43 cde
3.0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	3.88±0.38 cd
3.0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	4.75±0.75 bc
4.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	4.88±0.72 bc
4.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	5.50±0.84 ab
4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	6.50±0.87 a
F-test	**

** = has a significant effect at the 0.01 test level; numbers followed by the same letter in the same column are not significantly different based on the BNJ test at the α = 5% level.

The treatment with 4.5 ml/L nitrophenol compound + 10 g/polybag NPK (Table 5) produced the highest dry weight, namely 4.38 g, higher than the control (0 ml/L nitrophenol compound + 0 g/polybag NPK), which had a dry weight of 2.05 g. There is a clear linear relationship between root volume data (Table 4) and dry weight (Table 5). The high root volume in the 4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK (6.50 ml) treatment allows plants to absorb water and NPK nutrients from the growing medium more widely and intensively. This increased nutrient uptake automatically increases the plant's metabolic rate, which ultimately accumulates as dry plant mass (biomass).

Table 5. Concentration of nitrophenol compounds and dose of NPK fertilizer on the dry weight of cocoa seedlings 16 weeks after planting

Treatment	Dry Weight of Seedlings (g)
0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	2.05±0.05 d
0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	2.15±0.09 d
0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	2.23±0.10 d
1.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	2.35±0.06 d
1.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	2.43±0.05 cd
1.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	2.73±0.13 bcd
3.0 ml/L nitrophenol compound + 0 g/ *polybag* NPK	2.85±0.24 bcd
3.0 ml/L nitrophenol compound + 5 g/ *polybag* NPK	3.00±0.35 bcd
3.0 ml/L nitrophenol compound + 10 g/ *polybag* NPK	3.18±0.35 abcd
4.5 ml/L nitrophenol compound + 0 g/ *polybag* NPK	3.60±0.56 abc
4.5 ml/L nitrophenol compound + 5 g/ *polybag* NPK	3.88±0.52 ab
4.5 ml/L nitrophenol compound + 10 g/ *polybag* NPK	4.38±0.69 a
F-test	**

** = has a significant effect at the 0.01 test level; numbers followed by the same letter in the same column are not significantly different based on the BNJ test at the α = 5% level.

The dry weight of cocoa seedlings reached 4.38 g at 16 weeks post-planting (WAP) with a plant height approaching 46 cm, indicating vigorous seedling condition. A high dry weight indicates the amount of photosynthates successfully synthesized and stored as plant biomass (Lubis et al., 2020; Ramadhani et al., 2024).

The combination of a nitrophenol compound concentration of 4.5 ml/L and an NPK fertilizer dose of 10 g/polybag produced the highest values for all measured parameters. This treatment was higher than other dose combinations at both lower nitrophenol concentrations and different NPK doses, as shown in Figure 2.

Figure 2. Response of nitrophenol compound concentration and NPK fertilizer dose on cocoa seedling growth 16 weeks after planting (a) 4.5 ml/L nitrophenol compound + 10 g/ *polybag*, (b) 4.5 ml/L nitrophenol compound + 5 g/ *polybag*, (c) 4.5 ml/L nitrophenol compound + 0 g/ *polybag*, (d) 3.0 ml/L nitrophenol compound + 10 g/ *polybag*, (e) 3.0 ml/L nitrophenol compound + 5 g/ *polybag*, (f) 3.0 ml/L nitrophenol compound + 0 g/ *polybag*, (g) 1.5 ml/L nitrophenol compound + 10 g/ *polybag*, (h) 1.5 ml/L nitrophenol compound + 5 g/ *polybag*, (i) 1.5 ml/L nitrophenol compound + 0 g/ *polybag*, (j) 0 ml/L nitrophenol compound + 10 g/ *polybag*, (k) 0 ml/L nitrophenol compound + 5 g/ *polybag* and (l) 0 ml/L nitrophenol compound + 0 g/ *polybag*.

Seedlings in the 4.5 ml/L nitrophenol compound + 10 g polybag NPK treatment had higher tissue density than in other treatments. This high dry mass is a very important energy reserve for cocoa seedlings to withstand transplanting shock (stress when moving plants) when they are later moved to the field. Several studies have shown that good seedling quality is due to nutrient absorption. Providing the appropriate concentration of nitrophenol compounds and the right dose of NPK fertilizer can improve cocoa seedling growth, thereby increasing plant height, stem diameter, number of leaves, root volume, and seedling dry weight (Habeahan et al., 2021; Prasetyo et al.,

2023; Ramadhani et al., 2024).

4. Conclusion

Based on the results of research on the vegetative response of cocoa seedlings to the application of nitrophenol compounds and NPK fertilizer, the following conclusions can be drawn that the interaction between nitrophenol compounds and NPK fertilizer significantly affects plant height, stem diameter, leaf number, root volume, and cocoa seedling dry weight. The combination of a nitrophenol compound concentration of 4.5 ml/L and an NPK fertilizer dose of 10 g per polybag produced the highest results across all observed parameters compared to other treatments. The administration of nitrophenol compounds can effectively enhance nutrient absorption from NPK fertilizers, thereby promoting the growth of more vigorous cocoa seedlings.

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