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The effects of different concentrations of growth regulators on the *in vitro* multiplication of potato (*Solanum tuberosum* L.)

Farklı konsantrasyonlardaki büyüme düzenleyicilerin patatesin (*Solanum tuberosum* L.) *in vitro* çoğalması üzerine etkileri

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ABSTRACT

Objective: This research aims to study the effect of kinetin and NAA concentration interaction on the growth and multiplication of potato planlets (*Solanum tuberosum* L.) *in vitro*.

Material and Methods: This research was conducted at the Tissue Culture Laboratory, Faculty of Agriculture, Brawijaya University from December 2023 to March 2024. The research was conducted in a randomized group design with two factors. The first factor is the GR Naphthalene Acetic Acid (NAA) with 4 concentration levels, 0 ppm, 0.25 ppm, 0.50 ppm and 0.75 ppm. The second factor is Kinetin with 4 concentration levels, 0 ppm, 2.5 ppm, 5 ppm and 7.5 ppm.

Results: There is an interaction in the variable number of shoots, number of leaves, number of roots, planlet height and shoot emergence time. The number of shoots and the number of leaves have linear results or directly proportional to the growth of potato planlets. The addition of kinetin and NAA with the highest level of 7.5 ppm Kinetin and 0.75 ppm NAA can reduce the results on all observation variables.

Conclusion The addition of Kinetin 7.5 ppm and NAA 0.25 ppm interacted and produced higher growth in number of shoots (0.46%), number of leaves (0.27%) and number of roots of potato planlets (0.43%) compared to without the addition of kinetin and without the addition of NAA.

ÖZ

Amaç: Bu araştırma, kinetin ve NAA konsantrasyon etkileşiminin *in vitro* patates (*Solanum tuberosum* L.) fidelerinin büyümesi ve çoğalması üzerindeki etkisini incelemeyi amaçlamaktadır.

Materyal ve Yöntem: Bu araştırma, Aralık 2023 - Mart 2024 tarihleri arasında Brawijaya Üniversitesi, Ziraat Fakültesi, Doku Kültürü Laboratuvarında yürütülmüştür. Araştırma, iki faktörlü tesadüfi grup tasarımında yürütülmüştür. İlk faktör, 0 ppm, 0.25 ppm, 0.50 ppm ve 0.75 ppm olmak üzere 4 konsantrasyon seviyesine sahip Naftalin Asetik Asit (NAA) olmuştur. İkinci faktör ise 0 ppm, 2.5 ppm, 5 ppm ve 7.5 ppm olmak üzere 4 konsantrasyon seviyesine sahip Kinetin'dir.

Araştırma Bulguları: Sürgün sayısı, yaprak sayısı, kök sayısı, bitki boyu ve sürgün çıkış zamanı değişkenlerinde bir etkileşim gözlenmiştir. Sürgün sayısı ve yaprak sayısı, patates fidelerinin büyümesiyle doğrusal veya doğru orantılı sonuçlara sahiptir. En yüksek seviyede 7,5 ppm Kinetin ve 0,75 ppm NAA ile kinetin ve NAA'nın eklenmesi, tüm gözlem değişkenlerindeki sonuçları azaltabilir.

Sonuç: Kinetin 7,5 ppm ve NAA 0,25 ilavesi etkileşime girmiş ve kinetin ilavesiz ve NAA ilavesiz durumlara kıyasla patates fidelerinin sürgün sayısında (%0,46), yaprak sayısında (%0,27) ve kök sayısında (%0,43) daha yüksek büyüme sağlamıştır.

Keywords: Growth regulators, *in vitro*, kinetin, multiplication, Naphthalene Acetic Acid (NAA), potato planlets

Anahtar sözcükler: Büyüme düzenleyiciler, *in vitro*, kinetin, çoğaltma, Naftalin Asetik Asit (NAA), patates fideleri

INTRODUCTION

Potato plant (*Solanum tuberosum* L.) is one type of plant that is included in horticultural and field crops. Potato plants produce tubers that can be utilized as a food source. The nutritional content in 100 g of potatoes contains 75 g of water, 19 g of carbohydrates, 0.1 g of fat, vitamins B1, B2, B6 and B9 (Khalid et al., 2021). The demand for potato production in Indonesia is currently increasing. The increase in production is due to the increase in population and people's consumption patterns. According to the Directorate General of Horticulture, Ministry of Agriculture (2023) potato crop production has increased from 2020-2022 by 1 282 768 tons to 1 503 998 tons. The current increase in potato crop production affects the amount of seed used in the form of tubers. Seed potatoes have increased, causing the continuous use of tubers and an increase in the number of imports. According to the Central Bureau of Statistics (2022) in 2021, the need for the amount of seed potatoes in Indonesia reached 143 740 tons, while the available seeds were 12 361 tons consisting of domestic production of 7,045 tons and imported seeds of 5,316 tons.

The continuous use of potato tubers from previous harvests leads to a decrease in seed quality. Decreased seed quality can lead to decreased production yields. Decreased seed quality can be a limiting factor in potato production. According to Rout et al. (2022), quantity of good quality planting material in developing countries is a major problem. Based on this, potato seeds used by farmers are imported seeds or self-produced seeds that have lower quality. Long-term use of previously produced seed potatoes leads to pathogen accumulation and degeneration of seed quality Rout et al. (2022). Bacteria, fungus and nematodes are examples of soil-borne pathogens that build up in the soil and harm both seed and tubers. Therefore, seed potato propagation is needed to produce a large number of seeds, virus-free and in a fairly short time. One technique that can be used is tissue culture (*in vitro*).

In vitro techniques in potato, planlet propagation can be successful with several factors such as carbon source, growth regulators (GR), environmental conditions, light, genotype and explant type. *In vitro* culture, GR that can be used to enhance the process of plant growth and morphogenesis consist of cytokinins and auxins (Sharde et al., 2023). In general, auxins used in *in vitro* culture media have a function to start cell division and the initiation of leaves before the initiation of lateral roots which has an important role in meristem formation (Mehbub et al., 2022). Naphthalene Acetic Acid (NAA) is one of the auxin GR used in this study and Kinetin from the cytokinin group. GR Kinetin is used in *in vitro* culture because it has an effect on cell division (Trypuc et al., 2016). Research conducted by Ni'mah et al. (2012) showed that the use of kinetin with a concentration of 5 ppm and 40 g sucrose in potato plants was able to generate the greatest quantity of shoots, namely 10 shoots. While giving NAA with 0.50 ppm can produce the highest number of roots, namely 10.19 roots (Lestari et al., 2018). The balance of GR contained in *in vitro* culture media can affect planlet growth. Shoot induction can be produced by using a comparison of cytokinin in the optimum concentration with auxin in a lower concentration or without auxin. Therefore, this study is expected to ascertain how kinetin and NAA affect potato planlets growth.

MATERIALS and METHODS

Study area

This research was conducted at the Tissue Culture Laboratory, Faculty of Agriculture, Brawijaya University. This research started in December 2023 and continued until March 2024.

Experimental design

The research was conducted with a group randomized design with two factors. The first factor was Naphthalene Acetic Acid (NAA) with 4 concentration levels, namely 0 ppm, 0.25 ppm, 0.50 ppm and 0.75 ppm. The second factor is the GR Kinetin with 4 concentration levels, namely 0 ppm, 2.5 ppm, 5 ppm and 7.5 ppm. There were 16 treatment combinations and then repeated three times so there were 48 observation units. K1: without kinetin, K2: kinetin 2,5 ppm, K3: kinetin 5 ppm and K4: kinetin 7,5 ppm.

Media used for micro propagation

In this experiment, MS medium (Murashige & Skoog, 1962) used in culture media potato with growth regulators cytokinin and auxin:

(a) Macronutrients: NH_4NO_3 , KNO_3 , $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, KH_2PO_4 , $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$

(b) Micronutrients: H_3BO_3 , $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, Cu , $\text{Na}_2\text{M}_0\text{O}_4 \cdot 7\text{H}_2\text{O}$, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, Na_2EDTA

(c) Vitamins: Tiamin HCl, Piridoksin HCl, Asam nikotinat, Glycine, Myo-inositol

(d) Sucrose: 30 g/l using distilled water

(e) Addition of GR: stock solution of the growth regulator is added at the appropriate concentration at the treatment level

(f) Adjust the pH of the medium: to 5.5 - 5.8 using a digital pH meter with 0.1N HCl, or 0.1N NaOH (if necessary) before adding the agar

(g) Add of agar: Add 7 gm/l agar and heat using a magnetic stirrer until melt completely

Propagation of planting material

Planting media material was used from potato tubers that have 1 - 2 cm long shoots. The shoots were cut and sterilized using detergent for 5 minutes. After that, the explants were rinsed and put in a bottle containing a solution of bactericide and fungicide and shaken for 15 minutes. The next step was soaked using 15% Clorox liquid for 5 minutes. After that, the explants were then stored in a bottle containing distilled water and planted on media in a Laminar Air Flow Cabinet (LAFC). Planting materials used as potato variety Granola Kembang.

Multiplication of potato planlets

The multiplication process was carried out using explants that have become planlets. The planlets used as research material were planlets from the third subculture of axillary shoots. Explants in the shoots were then planted on media that had been added with GR treatment.

Incubation

Culture bottles were kept in an incubation room at a temperature of 20-25 °C. Maintenance activities were carried out by separating culture bottles that experience contamination caused by bacteria and fungi from the incubation room, performing the subculture process on potato planlets and spraying 70% alcohol on all culture bottles every day.

Data collection

The observation variables in this study were the number of shoots, number of leaves, number of roots, planlet height, shoot emergence time and root emergence time. Variable measurements were carried out at the age of 7, 14, 21 and 28 days after inoculation (DAI) except for the variable of shoot emergence time and root emergence time. Measurement of planlet height was done using a ruler.

Data analysis

Data were analyzed using analysis of variance (ANOVA) with a real level of 0.05 considered significant. Comparison of means was done by the Honest Significant Difference test using R Studio version 2024.12.0 and Microsoft Excel version 10.0.

RESULTS and DISCUSSION

Number of shoots

The growth pattern of the number of shoots of potato planlets showed a higher number of shoots with the addition of kinetin 5 ppm with no addition of NAA (Figure 1a). GR with 0.25 ppm NAA with 2.5 ppm kinetin showed a higher number of potato shoots (Figure 1b). GR with 2.5 ppm kinetin and 0.50 ppm NAA showed a lower number of shoots, but not significantly different from 7.5 ppm kinetin and 0.50 ppm NAA (Figure 1c). The addition of kinetin 2.5 ppm and NAA 0.75 ppm showed a higher number of shoots compared to the addition of kinetin 5 ppm, 7.5 ppm and without the addition of kinetin (Figure 1d).

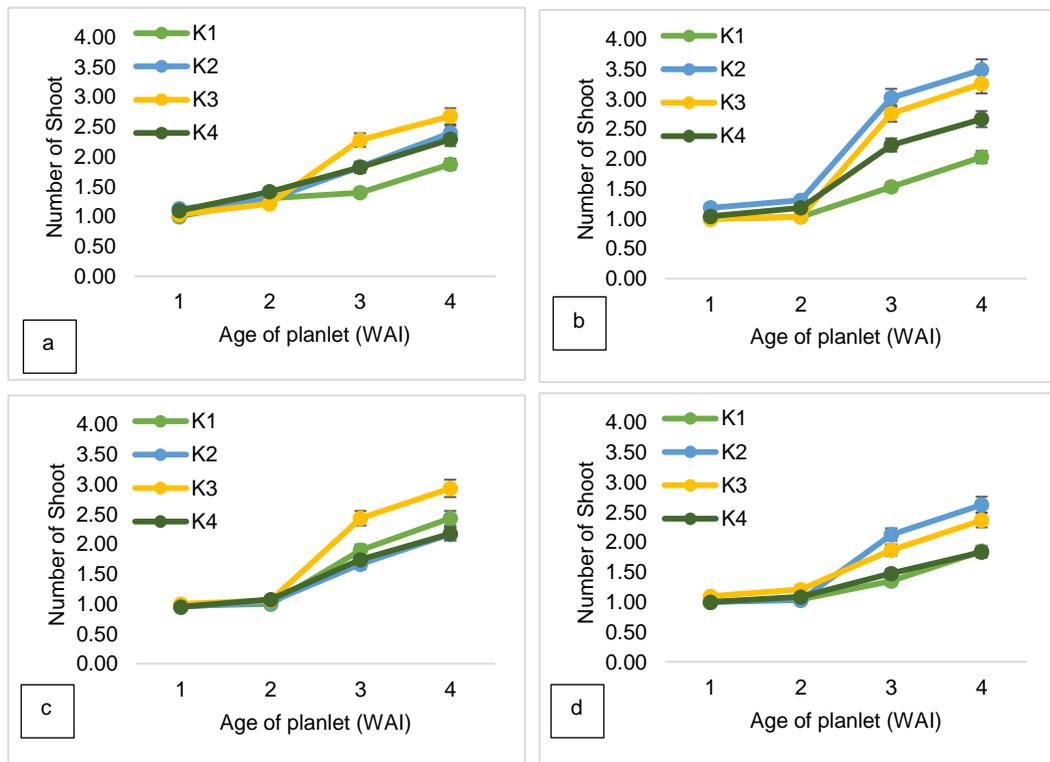


Figure 1. Growth pattern of number of shoot of potato planlets at NAA concentration (a) 0 ppm, (b) 0.25 ppm, (c) 0.50 ppm, (d) 0.75 ppm with different addition of kinetin.

Şekil 1. Farklı kinetin ilavesiyle (a) 0 ppm, (b) 0.25 ppm, (c) 0.50 ppm, (d) 0.75 ppm NAA konsantrasyonunda patates fidelerinin sürgün sayısının büyüme modeli.

According to the results of the analysis of variance, there was an interaction between the concentration of Kinetin and NAA in the culture media on the number of shoots of potato planlets at the age of 4 weeks after inoculation (WAI). *In vitro* culture media without kinetin + NAA 0.50 ppm and NAA 0.25 ppm produced higher shoots compared to culture media without the addition of kinetin and without NAA and without GR with kinetin + NAA 0.75 ppm (Table 1). The addition of kinetin 2.5 ppm + NAA 0.25 ppm produced a higher number of shoots (0.38%) compared to the addition of kinetin 2.5 ppm + NAA 0.50 ppm. The addition of 5 ppm kinetin + 0.25 ppm NAA and 0.50 ppm NAA produced a higher number of shoots compared to planlets grown on media with GR 5 ppm kinetin + no addition of NAA and 0.75 ppm NAA. Meanwhile, the addition of kinetin 7.5 ppm + NAA 0.75 ppm produced a lower number of shoots (1.83 shoots) compared to the addition of kinetin 7.5 ppm + NAA 0.25 ppm.

Table 1. Interaction between the addition of kinetin and NAA concentration on the number of shoots of potato planlets at age 4 WAI**Çizelge1.** Aşılardan 4 hafta sonra patates fidelerinin sürgün sayısı üzerine kinetin ilavesi ve NAA konsantrasyonu arasındaki etkileşim

Treatments	Average number of shoots of potato planlets at 4 WAI				HSD 5%
	Concentration NAA (ppm)				
Concentration Kinetin (ppm)	0	0,25	0,50	0,75	
0	1,88 b B	2,03 ab C	2,43 a B	1,85 b B	0,43
2,5	2,40 c A	3,49 a A	2,17 c B	2,63 b A	
5	2,68 bc A	3,26 a A	2,93 ab A	2,37 c A	
7,5	2,29 ab AB	2,67 a B	2,18 bc B	1,83 c B	
HSD 5%	0,43				
CV (%)	11,6				

* Based on the 5% HSD test, mean values followed by the same small letters in the same row and the same uppercase letters in the same column indicate results that are not significantly different. WAI (Week After Inoculation).

The number of shoots showed a significant interaction with the addition of Kinetin and NAA. According to North (2012), at the time of shoots formation requires a high concentration of cytokinin and a low amount of auxin. In this treatment, the amount of NAA that is significantly different is at the lowest level of 0.25 ppm. NAA which acts as auxin is absorbed by the plant tissue that will activate the energy of food reserves and is able to increase cell division, elongation and differentiation that can form shoots and shoot elongation (Aiman et al., 2022).

Number of leaves

The growth pattern of the number of leaves without the addition of NAA and without the addition of kinetin showed a lower number of leaves compared to the addition of no NAA with kinetin 2.5, 5 and 7.5 ppm (Figure 2a). GR with 0.25 ppm NAA with 2.5 ppm kinetin showed a higher number of leaves compared to planlets grown on media with 0.25 ppm NAA and 5 ppm kinetin, 7.5 ppm and without the addition of kinetin (Figure 2b). Giving 0.50 ppm NAA with all concentrations of kinetin did not produce significantly different number of leaves (Figure 2c). *In vitro* culture media with NAA 0.75 ppm and kinetin 7.5 ppm showed a lower number of leaves compared to the addition of NAA 0.75 ppm with kinetin 2.5 ppm, 5 ppm and without the addition of kinetin (Figure 2d).

Based on the results of the analysis of variance, there was an interaction between the concentration of Kinetin and NAA in the culture medium on the number of shoots of potato planlets at 4 WAI. Potato planlets on *in vitro* culture media without kinetin + NAA 0.50 ppm produced a higher number of leaves but not significantly different from media without kinetin + NAA 0.25 ppm (Table 2). The addition of kinetin 2.5 ppm + NAA 0.25 ppm produced a higher number of leaves (0.18%) compared to the addition of kinetin 2.5 ppm without the addition of NAA. Giving kinetin 5 ppm + NAA 0.25 ppm produced a higher number of leaves but not significantly different from the addition of kinetin 5 ppm with NAA 0.50 ppm, 0.75 ppm and without of NAA. While the addition of kinetin 7.5 ppm + NAA 0.75 ppm produced a lower number of leaves (5.91 strands) compared to the addition of kinetin 7.5 ppm with NAA 0.25 ppm, 0.50 ppm and without the addition of NAA.

Growth in number of leaves of potato planlets has a linear response with the growth of the number of shoots. The variable number of leaves showed that the addition of kinetin 2.5 ppm with NAA 0.25 ppm produced a higher number of leaves compared to other treatments, which amounted to 9.70 leaves, but was not significantly different from kinetin 5 ppm with NAA 0.25 ppm, which was 9.10 leaves. This is thought to be because the process of forming potato explant leaves requires cytokinin GR which acts as a

basic ingredient to spur the process of cell division. According to Lestari et al. (2018) cytokinin contained in plants will be translocated from the roots which can stimulate leaf growth. In addition, exogenous cytokinin can increase the number of potato planlet leaves optimally at a kinetin concentration of 2.5 ppm. The existence of one leaf is equivalent to the existence of one node so that in each node of potato planlets there are axillary shootss that can encourage shoot growth (Husna et al., 2014).

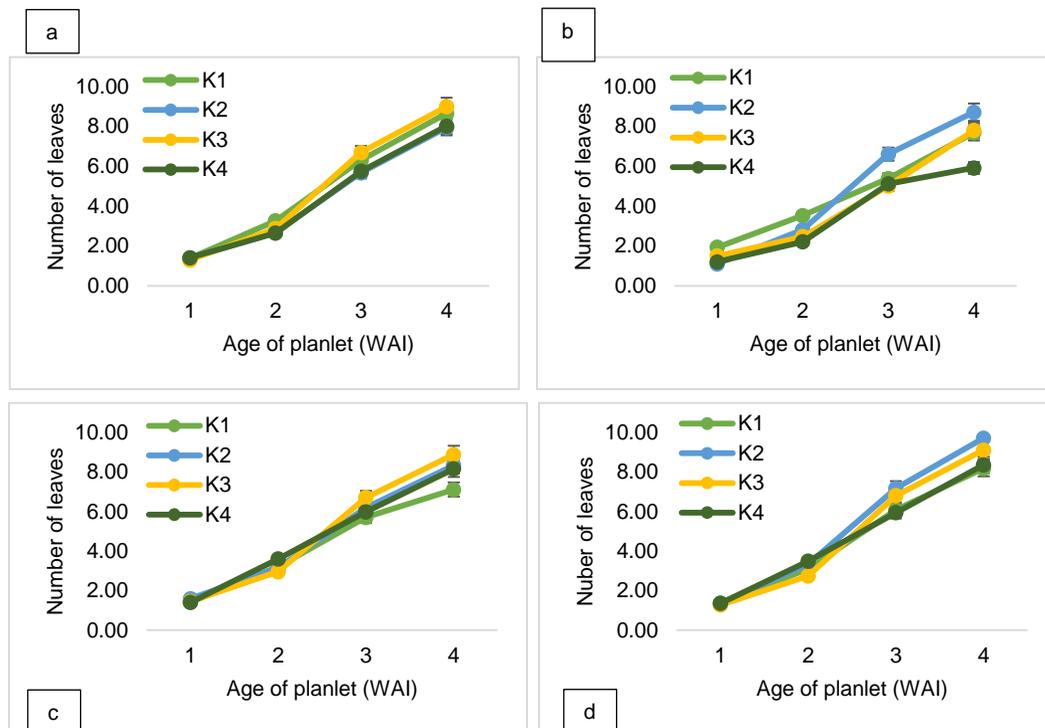


Figure 2. Growth pattern of number of leaves of potato planlets NAA concentration (a) 0 ppm; (b) 0.25 ppm; (c) 0.50 ppm; (d) 0.75 ppm with different addition of kinetin.

Şekil 2. Farklı kinetin ilavesiyle (a) 0 ppm, (b) 0.25 ppm, (c) 0.50 ppm, (d) 0.75 ppm NAA konsantrasyonunda patates fidelerinin yaprak sayısının büyüme modeli.

Table 2. Interaction between the addition of kinetin and NAA concentration on the number of leaves of potato planlets at age 4 WAI

Çizelge 1. Aşılardan 4 hafta sonra patates fidelerinin yaprak sayısı üzerine kinetin ilavesi ve NAA konsantrasyonu arasındaki etkileşim

Treatments	Average number of leaves of potato planlets at 4 WAI				HSD 5%
	Concentration NAA (ppm)				
Concentration Kinetin (ppm)	0	0,25	0,50	0,75	
0	7,10 c B	8,17 ab C	8,63 a AB	7,68 bc C	0,92
2,5	8,32 b A	9,70 a A	7,93 b B	8,70 b A	
5	8,87 a A	9,10 a AB	8,98 a A	7,79 b AB	
7,5	8,14 a A	8,35 a BC	8,01 a B	5,91 b C	
HSD 5%	0,92				
CV (%)	7,3				

* Based on the 5% HSD test, mean values followed by the same small letters in the same row and the same uppercase letters in the same column indicate results that are not significantly different. WAI (Week After Inoculation).

Growth in number of leaves of potato planlets has a linear response with the growth of the number of shoots. The variable number of leaves showed that the addition of kinetin 2.5 ppm with NAA 0.25 ppm produced a higher number of leaves compared to other treatments, which amounted to 9.70 leaves, but

was not significantly different from kinetin 5 ppm with NAA 0.25 ppm, which was 9.10 leaves. This is thought to be because the process of forming potato explant leaves requires cytokinin GR which acts as a basic ingredient to spur the process of cell division. According to Lestari et al. (2018) cytokinin contained in plants will be translocated from the roots which can stimulate leaf growth. In addition, exogenous cytokinin can increase the number of potato planlet leaves optimally at a kinetin concentration of 2.5 ppm. The existence of one leaf is equivalent to the existence of one node so that in each node of potato planlets there are axillary shoots that can encourage shoot growth (Husna et al., 2014).

Number of roots

The growth pattern of the number of roots without the addition of NAA and without the addition of kinetin showed a higher number of roots compared to *in vitro* culture media without the addition of NAA with the addition of kinetin 2.5, 5 and 7.5 ppm (Figure 3a). The addition of NAA 0.25 ppm and kinetin 2.5 ppm showed a higher number of roots compared to *in vitro* culture media with the addition of NAA 0.25 ppm and kinetin 5 ppm, 7.5 ppm and without the addition of kinetin (Figure 3b). The addition of NAA 0.50 ppm showed a significantly different number of roots at all kinetin concentrations with the addition of NAA 0.50 ppm and kinetin 2.5 ppm showed a higher number of roots (Figure 3c). The addition of NAA 0.75 ppm and kinetin 7.5 ppm showed a lower number of roots but not significantly different from planlets with NAA 0.75 ppm and kinetin 5 ppm (Figure 3d).

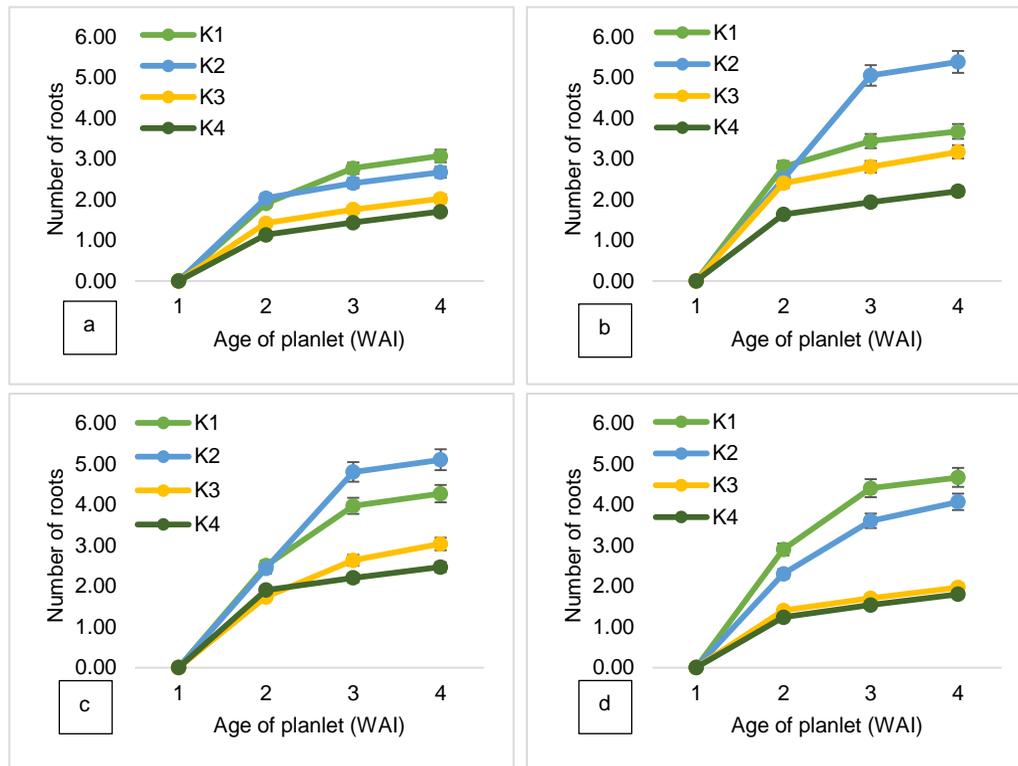


Figure 3. Growth pattern of number of roots potato planlets at NAA concentration (a) 0 ppm; (b) 0.25 ppm; (c) 0.50 ppm; (d) 0.75 ppm with different addition of kinetin.

Şekil 3. Farklı kinetin ilavesiyle (a) 0 ppm, (b) 0.25 ppm, (c) 0.50 ppm, (d) 0.75 ppm NAA konsantrasyonunda patates fidelerinin kök sayısının büyüme modeli.

Based on the results of the analysis of variance, there was an interaction between the concentration of Kinetin and NAA in the culture media on the number of roots of potato planlets at 4 WAI. *In vitro* culture media without the addition of kinetin + NAA 0.75 ppm produced a higher number of roots

compared to NAA 0.25 and without the addition of NAA (Table 3). The addition of kinetin 2.5 ppm + NAA 0.25 ppm and kinetin 2.5 ppm + NAA 0.50 ppm produced a higher number of roots (5.38 roots and 5.10 roots) compared to the addition of kinetin 2.5 ppm with NAA 0.75 ppm and without NAA. The addition of 5 ppm kinetin + 0.25 ppm NAA produced a higher number of roots, but not significantly different from planlets grown on *in vitro* culture with 0.50 ppm NAA. GR with 7.5 ppm kinetin and with all NAA concentrations did not produce significantly different number of roots.

Table 3. Interaction between the addition of kinetin and NAA concentration on the number of roots of potato planlets at age 4 WAI

Çizelge 2. Aşılardan 4 hafta sonra patates fidelerinin kök sayısı üzerine kinetin ilavesi ve NAA konsantrasyonu arasındaki etkileşim

Treatments	Average number of roots of potato planlets at 4 WAI				HSD 5%
	Concentration NAA (ppm)				
Concentration Kinetin (ppm)	0	0,25	0,50	0,75	
0	3,07 c A	3,67 bc B	4,27 ab B	4,67 a A	0,77
2,5	2,67 c AB	5,38 a A	5,10 a A	4,07 b A	
5	2,02 b BC	3,17 a B	3,03 a C	1,97 b B	
7,5	1,70 a C	2,20 a C	2,47 a C	1,80 a B	
HSD 5%	0,77				
CV (%)	5,9				

* Based on the 5% HSD test, mean values followed by the same small letters in the same row and the same uppercase letters in the same column indicate results that are not significantly different. WAI (Week After Inoculation).

In observing the growth of the number of roots, the treatment of kinetin 2.5 ppm with NAA 0.25 ppm showed a higher number of roots than the other treatments, namely the number of roots of 5.38 roots. This shows that the number of roots will have better results if the addition of auxins and cytokinins is appropriate. Giving different concentrations of kinetin and NAA can increase explant morphogenesis in planlet formation, including root formation, so that the combination of kinetin and NAA can provide a balanced effect on the number of roots. However, the higher concentration of NAA showed a lower number of roots. According to Arimarsetiowati (2012) the use of NAA in culture media with high concentrations can cause wounding in plants.

Planlet height

The growth pattern of potato planlet height showed lower planlet height with of 2.5 ppm kinetin + no NAA addition (Figure 4a). Culture medium with of 0.25 ppm NAA and no addition of kinetin showed higher planlet height compared to the addition of 2.5, 5 and 7.5 ppm kinetin (Figure 4b). The addition of NAA 0.50 ppm with no addition of kinetin showed higher planlet height, and the addition of kinetin 5 ppm showed lower planlet height (Figure 4c). The addition of NAA 0.75 ppm with no kinetin showed higher planlet height compared to the addition of kinetin 2.5, 5 and 7.5 ppm (Figure 4d).

Based on the results of the analysis of variance, there was an interaction between the concentration of kinetin and NAA in the culture medium on the height of potato planlets at 4 WAI. *In vitro* culture media without the addition of kinetin and of 0.75 ppm NAA produced higher planlet height (6.02 cm) but not significantly different from GR with of 0.50 ppm NAA (Table 4). GR with of 2.5 ppm kinetin and 0.25 ppm NAA and no NAA produced higher planlet height (0.20%) compared to the height of planlets grown on media with 0.50 and 0.75 ppm NAA. The addition of 5 ppm kinetin + no addition of NAA and 7.5 ppm kinetin + no addition of NAA produced higher planlet height compared to the addition of 0.25, 0.50 and 0.75 ppm NAA.

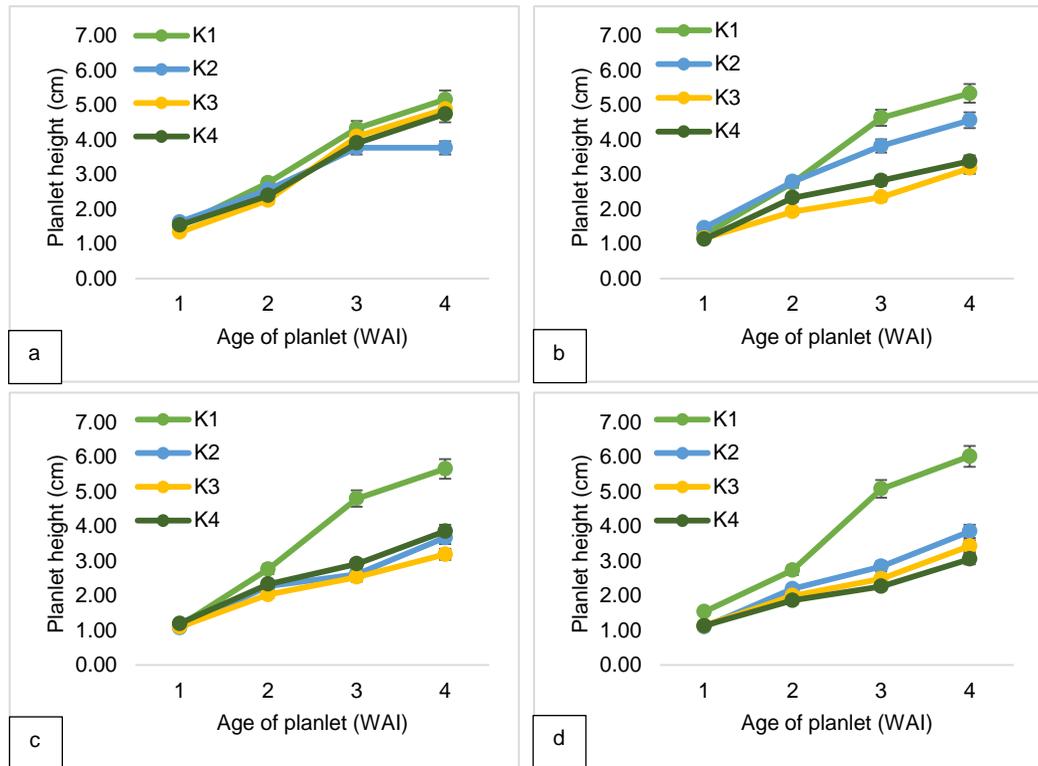


Figure 4. Growth pattern of planlet height of potato planlets at NAA concentration (a) 0 ppm; (b) 0.25 ppm; (c) 0.50 ppm; (d) 0.75 ppm with different addition of kinetin.

Şekil 4. Farklı kinetin ilavesiyle (a) 0 ppm, (b) 0.25 ppm, (c) 0.50 ppm, (d) 0.75 ppm NAA konsantrasyonunda patates fidelerinin bitki boyu büyüme modeli.

In the observation of the growth of potato planlet height, the treatment without the addition of kinetin with NAA 0.75 ppm showed a higher planlet height than the other treatments with a height of 6.02 cm. The addition of kinetin concentration in the *in vitro* culture media can inhibit the growth of planlet height. This is thought to be because there are endogenous cytokinin hormones found in potatoes that are already able to encourage the growth of planlet height. According to Setiawati et al. (2018), the concentration of GR that is too high for certain plants can trigger the synthesis of ethylene which can inhibit the process of cell elongation, and inhibit the increase in planlet height.

Table 4. Interaction between the addition of kinetin and NAA concentration on the planlet height at age 4 WAI

Çizelge 3. Aşılardan 4 hafta sonra bitki boyu üzerine kinetin ilavesi ve NAA konsantrasyonu arasındaki etkileşim

Treatments	Average planlet height of potato planlets at 4 WAI				HSD 5%
	Concentration NAA (ppm)				
Concentration Kinetin (ppm)	0	0,25	0,50	0,75	
0	5,17 b A	5,34 b A	5,66 ab A	6,02 a A	0,63
2,5	4,57 a A	4,57 a B	3,67 b BC	3,86 b B	
5	4,89 a A	3,19 b C	3,19 b C	3,43 b BC	
7,5	4,75 a A	3,39 bc C	3,86 b B	3,06 c C	
HSD 5%	0,63				
CV (%)	9,8				

* Based on the 5% HSD test, mean values followed by the same small letters in the same row and the same uppercase letters in the same column indicate results that are not significantly different. WAI (Week After Inoculation).

Time emergence of roots

Based on the analysis of variance, there was no interaction between different concentrations of Kinetin and NAA. Separately, kinetin concentration produced a significant effect on root emergence time, while NAA concentration produced an unreal effect on root emergence time. *In vitro* culture media without the addition of kinetin resulted in faster root emergence time (10.6 DAI) but not significantly different from other kinetin additions (Table 5). The addition of NAA at all levels did not produce a significant effect on the time to root emergence of potato planlets.

Table 5. Mean root emergence time of potato planlets with various concentrations of kinetin and NAA

Çizelge 5. Farklı konsantrasyonlarda kinetin ve NAA uygulanan patates fidelerinin ortalama kök çıkış süresi

Treatments	Average time of emergence of potato planlet roots DAI
Concentration Kinetin (ppm)	
0	10,6 b
2,5	11,6 ab
5	12,9 ab
7,5	14,5 a
HSD 5%	3,65
Concentration NAA (ppm)	
0	12,5
0,25	11,7
0,50	11,4
0,75	13,2
HSD 5%	tn
CV (%)	12,6

* Means accompanied by the same letter in the same column and treatment indicate no significant difference based on 5% HSD test, tn: not significant. (DAI) Day After Inoculation.

In contrast to the number of roots, the variable of root emergence time showed that the provision of various concentrations of kinetin and NAA had no significant interaction on the variable. However, the addition of auxin to the culture media does not always increase the time of root emergence because the addition of auxin at certain concentrations can reduce the number and length of roots. According to Sulastrri et al. (2023) giving too high a concentration of NAA can inhibit the process of root elongation of plants; this happens because NAA that is too high can be toxic so that it disrupts the process of cell division in root formation. The endogenous auxin content found in potato planlets becomes an inhibitor during root formation. According to research conducted by Nurchasanah et al. (2022), the addition of NAA 0.1 ppm singly or a combination of NAA and BAP showed a toxic dose that affected the vegetative growth of potato explants.

Time of emergence of potato planlet shoots

Based on the results of the analysis of variance, there was an interaction between the concentration of Kinetin and NAA in the culture medium on the time of emergence of potato planlet shoots. Culture media without the addition of kinetin without the addition of NAA, NAA 0.25 ppm and NAA 0.50 ppm produced faster shoot emergence time compared to the addition of NAA 0.75 ppm (Table 6). The addition of kinetin 2.5 ppm without the addition of NAA resulted in faster shoot emergence time (3.63 DAI), but not significantly different from the addition of NAA 0.50 ppm. The addition of kinetin 5 ppm without the addition of NAA, NAA 0.25 ppm and 0.50 ppm resulted in faster shoot emergence time compared to the addition of NAA 0.75 ppm. Kinetin 7.5 ppm and without the addition of NAA produced faster shoot emergence time (3.51 DAI) compared to the addition of NAA 0.25, 0.50 and 0.75 ppm.

In the variable time of shoots emergence, the addition of kinetin 7.5 ppm, 5 ppm and 2.5 ppm with no addition of NAA showed a faster shoots emergence time than other treatments. The difference in shoot emergence time is thought to be influenced by the different concentrations of kinetin given. Giving kinetin in higher levels can accelerate the time of shoots emergence without the help of auxin GR. This is thought to be because there is endogenous auxin contained in potato explants, so that the role of exogenous auxin can inhibit cytokinin which is able to initiate shootsding. The endogenous hormone found in potato explants is in the apical meristem which is called the hormone auxin (Vernoux et al., 2010). The endogenous hormone auxin can trigger apical dominance. Apical dominance is directly related to the content of the hormone auxin contained in the apical meristem, the auxin has a role to regulate branching by affecting transport and factors that inhibit the growth of axillary shoots, as well as inhibiting the work of cytokinin hormones (Aiman et al., 2022).

Table 6. Interaction between the addition of kinetin and NAA concentration on the shoot emergence time of potato planlets

Çizelge 6. Patates fidelerinin sürgün çıkış süresi üzerine kinetin ilavesi ve NAA konsantrasyonu arasındaki etkileşim

Treatments	Average time of emergence of potato planlet shoots DAI				HSD 5%
	Concentration NAA (ppm)				
Concentration Kinetin (ppm)	0	0,25	0,50	0,75	
0	4,43 a B	5,14 a B	5,15 a BC	6,05 b A	
2,5	3,63 a AB	5,12 bc B	4,33 ab A	5,33 c A	0,80
5	4,24 a AB	4,73 a AB	4,38 a AB	5,61 b A	
7,5	3,51 a A	4,30 b A	5,68 c C	7,92 d B	
HSD 5%	0,80				
CV (%)	10,6				

* Based on the 5% HSD test, mean values followed by the same small letters in the same row and the same uppercase letters in the same column indicate results that are not significantly different. WAI (Week After Inoculation).

CONCLUSIONS

Based on the research on the effect of growth regulators on potato planlets, it can be concluded that the interaction between kinetin and NAA occurs in the variable of shoot emergence time, planlet height, number of shoots, number of roots and number of leaves. Recommendations that can be used are the addition of kinetin 2.5 ppm and NAA 0.25 ppm interactions occur and produce growth in the number of shoots (0.46%), the number of leaves (0.27%) and the number of roots of potato planlets (0.43%) higher than without the addition of kinetin and without the addition of NAA.

Data Availability

Data will be available upon request.

Author Contributions

Conception and design of the study: ASK, RNM; sample collection: ASK, RNM; analysis and interpretation of data: ASK, RNM; statistical analysis: ASK, RNM; visualization: ASK, RNM; writing manuscript: ASK, RNM.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that no ethics committee is required for this research.

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