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Improvement of yield and rhizome shelf-life of kencur (*Kaempferia galanga* L.) through application of naphthaleneacetic acid and benzyladenine

Akbar Saitama[1*], Darmawan Saptadi[1], Moch. Dawam Maghfoer[1], Eko Widaryanto[1]

[1] Faculty of Agriculture, Universitas Brawijaya, Malang, Indonesia
* Corresponding author's mail: akbarsaitama@ub.ac.id

ABSTRACT

Kencur is a medicinal plant of high economic value, yet its productivity and postharvest quality remain low due to limited cultivation techniques and short rhizome shelf life. This study aimed to determine the effect of combined applications of NAA (naphthaleneacetic acid) and BA (benzyladenine) on rhizome yield and shelf life at two harvest ages. The experiment was conducted at the Agro Techno Park Experimental Garden, Brawijaya University, using a factorial randomized block design (RBD) with three NAA concentrations (10, 20, 30 ppm) and four BA concentrations (0, 10, 20, 30 ppm), resulting in 12 treatment combinations replicated three times. Observed parameters included fresh rhizome weight at harvest ages of 6 and 8 months after planting (MAP), and weight loss during storage up to 30 days after harvest (DAH). Results showed that the interaction of NAA and BA significantly influenced rhizome weight and weight loss during storage. The combination of NAA 30 ppm + BA 30 ppm produced the highest weight, 60.32 g/plant at 6 MAP and 100.9 g/plant at 8 MAP. Moreover, the high-dose combination suppressed weight loss, maintaining 87.73% of initial weight (6 MAP) and 93.25% (8 MAP) at 30 DAH. Harvesting at 8 MAP was more optimal than at 6 MAP, as it yielded larger rhizomes with better storability.

Keywords: *Kaempferia galanga* L., naphthaleneacetic acid, benzyladenine, rhizome shelf-life.

INTRODUCTION

Kencur (*Kaempferia galanga* L.) is an important medicinal plant from Zingiberaceae family with high economic value. Its rhizomes are widely used as raw materials for traditional medicine, phytopharmaceuticals, culinary spices, and as a source of bioactive compounds such as ethyl p-methoxycinnamate (EPMC), flavonoids, and essential oils with anti-inflammatory, antimicrobial, and antioxidant properties. Demand for kencur continues to increase with the growth of the herbal and functional food industries. However, its productivity and postharvest quality remain low at the farmer level due to suboptimal cultivation practices and the inherently short shelf life of fresh rhizomes (Kochuthressia et al., 2012; Yang et al., 2018; Adianingsih et al., 2021)

Kencur is widely recognized for its medicinal and economic value, yet its cultivation continues to face significant challenges. In many farming communities, especially at the smallholder level, productivity remains low, and the quality of harvested rhizomes declines rapidly during storage. This is largely due to the reliance on traditional cultivation methods that have not evolved to meet modern production standards. Typically, these methods result in rhizomes with low biomass and high moisture content, which accelerates postharvest deterioration. As a result, substantial weight loss during storage is common, and the shelf-life of fresh rhizomes is often short (Dalilah et al., 2023; Nguyen et al., 2025). This limits the supply of high-quality kencur for industrial use and reduces its economic return for farmers. Recent studies have also emphasized that the poor storability of rhizomes is a pressing

issue that requires more targeted agronomic solutions (Hashiguchi et al., 2022).

One of the key obstacles in improving kencur production is the limited application of science-based agronomic practices, particularly in the use of plant growth regulators (PGRs). Most farmers do not yet incorporate hormonal treatments into their cultivation strategies, despite growing evidence of their effectiveness. Without such interventions, rhizomes often remain small and loosely structured, making them more vulnerable to shrinkage and spoilage during storage (Nguyen et al., 2025; Dalilah et al., 2023). Additionally, the timing of harvest plays a crucial role. When harvested too early, rhizomes may not have accumulated enough starch or developed robust tissue structures, which diminishes their ability to resist degradation (Panneerselvam and Jaleel, 2008; Rusmin et al., 2015).

Exogenous application of PGRs – particularly auxins and cytokinins – offers a promising strategy to enhance both rhizome yield and postharvest quality. Auxins such as naphthaleneacetic acid (NAA) are known to promote cell elongation, stimulate root and rhizome growth, and redirect photosynthates to storage organs (Leyser, 2006; Wijayati et al., 2005). Cytokinins like benzyladenine (BA), on the other hand, encourage cell division and delay senescence by maintaining membrane stability and reducing oxidative stress (Schaller et al., 2015). When applied in combination, these hormones can act synergistically, supporting not only growth but also physiological integrity – particularly important in crops like kencur where the rhizome is the primary economic product (Overvoorde et al., 2010; D'Aloia, 2011).

Research from related crops has shown encouraging results. In turmeric, for example, foliar applications of IAA improved rhizome biomass and the size of secretory tissues (Wijayati et al., 2005). Similarly, in *Eucalyptus cloeziana*, maintaining a balanced ratio between cytokinins and auxins enhanced shoot regeneration and micropropagation success (de Oliveira et al., 2022). Furthermore, hormonal treatments have been linked to improved nutrient and secondary metabolite profiles in storage tissues, which may translate to longer shelf-life and better nutritional value (Wierzbowska et al., 2007; Czapla et al., 2003).

Although extensive research has been conducted on the role of PGRs in enhancing vegetative growth and tissue development, there remains a significant lack of studies focusing specifically on the combined application of NAA and BA in *Kaempferia galanga*, particularly under field conditions. Most studies have either examined in vitro propagation techniques or focused on closely related species. Moreover, little attention has been paid to the relationship between harvest age and the effectiveness of hormonal treatment in improving both rhizome yield and storability. This represents a critical knowledge gap that must be addressed to optimize cultivation strategies for kencur.

Given the dual challenge of increasing productivity and enhancing postharvest storability, this study proposes a combined approach integrating hormonal treatment with harvest timing optimization. Specifically, the research investigates the effect of NAA and BA application at varying concentrations on the fresh rhizome weight and weight loss during storage at two harvest ages: 6 and 8 months after planting. The working hypothesis is that high-dose combinations of NAA and BA (30 ppm each) will synergistically improve rhizome biomass and structural integrity, thereby minimizing shrinkage during storage and extending shelf-life.

This study offers a novel contribution to the field by simultaneously evaluating both physiological yield and storage performance of *K. galanga* in response to PGR treatment across different harvest timings. While previous studies have typically focused on either yield or postharvest characteristics independently, this research seeks to integrate both dimensions in a unified experimental design. The findings are expected to guide the development of practical cultivation protocols that improve yield and quality while supporting postharvest handling strategies. Furthermore, the outcomes will contribute to enhancing the commercial viability of kencur farming by reducing postharvest losses and ensuring a more consistent supply of high-quality rhizomes for medicinal and industrial uses.

MATERIALS AND METHODS

The study was conducted from October 2024 to June 2025 at the Agro Techno Park Experimental Garden, Faculty of Agriculture, Brawijaya University, Jatikerto Village, Kromengan District,

Malang, at an altitude of 400 m above sea level. A factorial randomized block design (RBD) was used, consisting of two factors namely NAA concentration and BA concentration. NAA concentration (N_{10}: 10 ppm NAA; N_{20}: 20 ppm NAA; N_{30}: 30 ppm NAA), BA concentration (BA_0: 0 ppm BA; BA_{10}: 10 ppm BA; BA_{20}: 20 ppm BA; BA_{30}: 30 ppm BA). This resulted in 12 treatment combinations with three replications.

Fresh rhizome weight was measured destructively at harvest ages of 6 and 8 months after planting. Sixteen plants per plot were sampled at each harvest time. Rhizome weight loss during storage was observed up to 30 days after harvest (DAH), with measurements at 10-day intervals.

Collected data were analyzed using analysis of variance (ANOVA) at a 5% significance level. When significant effects were found, means were compared using the honest significant difference (HSD) test at the 5% level.

RESULTS

Rhizome weight at harvest (0 DAH) presented in Table 1 shows a significant increase under the combination of NAA 30 ppm + BA 30 ppm, reaching 60.32 g/plant. It was observed that the higher the combination of NAA and BA, the greater the rhizome weight produced. During storage (10, 20, and 30 DAH), rhizome weight decreased with longer storage time, indicating physiological shrinkage. The NAA 30 ppm + BA 30 ppm combination consistently maintained the highest weight across all time points, with 52.95 g/plant at 30 DAH, equivalent to 87.73% of the initial weight. In contrast, the low-dose combination (NAA 10 ppm + BA 0 ppm) showed greater shrinkage, with 28.65 g/plant (78.71% at 30 DAH).

Table 2 (harvest age of 8 months, NAA + BA combinations) indicates that rhizome weight at harvest (0 DAH) was higher compared to 6 months. The best treatment remained the NAA 30 ppm + BA 30 ppm combination, yielding the highest weight of 100.9 g/plant. During storage (10, 20, and 30 DAH), all treatments experienced weight loss, but the high-dose combination remained the most stable. At 30 DAH, the NAA 30 ppm + BA 30 ppm combination retained 94.21 g/plant, or 93.25% of the initial weight. Harvesting at 8 months produced higher rhizome weight and lower shrinkage, particularly under the high-dose combination.

Overall, the combination of NAA 30 ppm + BA 30 ppm provided the best results at both 6- and 8-month harvest ages, producing higher rhizome weight and lower shrinkage. Harvesting at 8 months was more advantageous than at 6 months, as it resulted in larger rhizomes with better storability.

DISCUSSION

The results of this study showed that the interaction between NAA and BA had a significant effect on rhizome weight and weight loss during storage. This effect can be explained through the physiological mechanisms of both hormones. NAA plays an important role in stimulating cell division, elongation, and differentiation of root and rhizome tissues. Auxin also facilitates the translocation of photosynthates into storage organs (rhizomes), thereby increasing carbohydrate reserves and secondary metabolites. This explains why increasing the NAA dose up to 30 ppm was able to enhance rhizome size and weight. BA functions to stimulate cell division and maintain meristematic activity in rhizome tissues. Cytokinins are also known to delay senescence by preserving cell membrane stability, slowing protein degradation, and reducing water loss. These effects support an increase in initial biomass as well as an extension of rhizome shelf life.

Auxins and cytokinins exhibit both antagonistic and synergistic interactions in regulating plant growth. At low doses, the effects are less visible; however, at the optimal dose (30 ppm NAA + 30 ppm BA), synchronization of cell division and enlargement occurs, resulting in greater biomass accumulation. This combination also helps maintain rhizome physiological integrity during storage, leading to lower weight loss compared to low-dose treatments.

In ex vitro cultivation, aside from genetic and environmental factors, hormones are also crucial in determining plant growth and development (Wijayati et al., 2005; Hashiguchi et al., 2022). Auxins and cytokinins are often combined to stimulate plant growth. Both are involved in cell division and cell expansion (Brondani ei al., 2018). Auxins and cytokinins are known to stimulate root and shoot

Table 1. Effect of NAA and BA interaction on rhizome weight and rhizome shelf-life of kencurat 6 months after planting

Rhizome weight (g plant^{-1}) at harvest (0 DAH)				
NAA concentration (ppm)	BA concentration (ppm)			
	0	10	20	30
10	36.31 a A (100%)	38.68 a A (100%)	40.88 a A (100%)	41.28 a A (100%)
20	39.75 a AB (100%)	43.25 a A (100%)	53.31 b B (100%)	55.85 b B (100%)
30	43.88 a B (100%)	55.19 b B (100%)	55.65 b B (100%)	60.32 b B (100%)
HSD 5% NAA	6.738			
HSD 5% BA	7.448			
% CV	6.984			
Rhizome weight (g plant^{-1}) at 10 DAH				
NAA concentration (ppm)	NAA concentration (ppm)			
	0	10	20	30
10	33.15 a A (91.23%)	35.53 a A (91.77%)	37.67 a A (92.13%)	38.03 a A (92.12%)
20	37.06 a AB (91.84%)	40.08 a A (92.65%)	50.13 b B (94.03%)	52.68 b B (94.32%)
30	40.64 a B (92.60%)	51.99 b B (94.15%)	52.41 b B (94.17%)	57.08 b B (94.62%)
HSD 5% NAA	6.569			
HSD 5% BA	7.262			
% CV	7.297			
Rhizome weight (g plant^{-1}) at 20 DAH				
NAA concentration (ppm)	NAA concentration (ppm)			
	0	10	20	30
10	31.41 a A (86.40%)	33.77 a A (87.19%)	36.13 a A (88.19%)	36.53 a A (88.49%)
20	35.28 a AB (87.43%)	38.23 a A (88.37%)	48.31 b B (90.62%)	51.18 b B (91.64%)
30	39.10 a B (89.06%)	50.45 b B (91.34%)	50.88 b B (91.39%)	55.59 b B (92.11%)
HSD 5% NAA	6.599			
HSD 5% BA	7.294			
% CV	6.984			
Rhizome weight (g plant^{-1}) at 30 DAH				
NAA concentration (ppm)	NAA concentration (ppm)			
	0	10	20	30
10	28.65 a A (78.71%)	31.00 a A (79.86%)	33.48 a A (81.83%)	34.02 a A (82.44%)
20	32.62 a AB (80.88%)	35.71 a A (82.43%)	45.52 b B (85.38%)	48.64 b B (87.10%)
30	36.58 a B (83.41%)	47.62 b B (86.10%)	48.34 b B (86.88%)	52.95 b B (87.73%)
HSD 5% NAA	6.836			
HSD 5% BA	7.556			
% CV	8.414			

Note: Values followed by the same lowercase letter within rows or uppercase letter within columns are not significantly different according to HSD test at the 5% level. Values in parentheses indicate rhizome shelf-life (%). DAH – days after harvest; CV – coefficient of variance.

Table 2. Effect of NAA and BA interaction on rhizome weight and rhizome shelf-life of kencur at 8 months after planting

Rhizome weight (g plant^{-1}) at Harvest (0 DAH)				
NAA concentration (ppm)	BA Concentration (ppm)			
	0	10	20	30
10	70.45 a A (100%)	83.15 b A (100%)	83.99 b A (100%)	85.35 b A (100%)
20	77.98 a B (100%)	81.00 a A (100%)	92.41 b B (100%)	91.37 b A (100%)
30	78.44 ab B (100%)	90.63 b B (100%)	93.53 bc B (100%)	100.9 c B (100%)
HSD 5% NAA	6.738			
HSD 5% BA	7.448			
% CV	6.984			
Rhizome weight (g plant^{-1}) at 10 DAH				
NAA concentration (ppm)	NAA Concentration (ppm)			
	0	10	20	30
10	69.13 a A (98.14%)	81.33 b A (97.83%)	82.66 b A (98.42%)	83.16 b A (97.52%)
20	76.88 a B (98.62%)	79.45 a A (98.09%)	90.86 b B (98.32%)	88.11 b A (96.45%)
30	76.43 a B (97.41%)	88.59 b B (97.75%)	91.48 bc B (97.82%)	97.42 c B (96.42%)
HSD 5% NAA	6.569			
HSD 5% BA	7.262			
% CV	7.297			
Rhizome weight (g plant^{-1}) at 20 DAH				
NAA concentration (ppm)	NAA concentration (ppm)			
	0	10	20	30
10	66.03 a A (93.73%)	78.23 b A (94.09%)	79.56 b A (94.72%)	80.06 b A (93.88%)
20	75.65 a B (97.04%)	78.22 a A (96.57%)	89.63 b B (96.99%)	86.88 b A (95.10%)
30	74.36 a B (94.77%)	86.51 b B (95.46%)	89.40 bc B (95.59%)	95.20 c B (94.23%)
HSD 5% NAA	6.599			
HSD 5% BA	7.294			
% CV	6.984			
Rhizome weight (g plant^{-1}) at 30 DAH				
NAA concentration (ppm)	NAA concentration (ppm)			
	0	10	20	30
10	64.71 a A (91.86%)	76.90 b A (92.51%)	78.44 b A (93.38%)	78.67 b A (92.27%)
20	73.63 a B (94.45%)	76.12 a A (93.37%)	87.03 b B (94.19%)	85.53 b A (93.61 %)
30	73.06 a B (93.09%)	85.89 b B (94.75%)	88.46 bc B (94.59%)	94.21 c B (93.25%)
HSD 5% NAA	6.836			
HSD 5% BA	7.556			
% CV	8.414			

Note: Values followed by the same lowercase letter within rows or uppercase letter within columns are not significantly different according to HSD test at the 5% level. Values in parentheses indicate rhizome shelf-life (%). DAH = days after harvest; CV: coefficient of variance.

development, but these phytohormones play dual and often overlapping roles in plant growth and development (Howell et al., 2003; Chandler, 2011). They are involved in the induction and development of root and shoot meristems, lateral branching and aerial organs, as well as reproductive organ formation (Overvoorde et al., 2010; D'Aloia, 2011). Thus, various growth characteristics are directly or indirectly influenced by changes in the level of either of these phytohormones (Schaller et al., 2015).

The effect of auxins and cytokinins on plants cultivated in the field is strongly influenced by the concentration of hormones applied. Research Wijayati (2005) on turmeric plants reported that foliar application of IAA from 1 to 4 months after planting, at one-month intervals, increased rhizome growth and yield. Concentrations up to 200 ppm IAA significantly increased fresh and dry rhizome weight. Another study Xu (2018) on Malus zumi found that application of 120 mg L^{-1} IBA optimized root development in M. zumi. Other work de Oliveira et al (2022), showed that ex vitro production of *Eucalyptus cloeziana* was optimal when auxin and cytokinin concentrations were balanced.

Auxins and cytokinins also influence the chemical composition of plant biomass (Wybouw and Rybel, 2019). The use of plant growth regulators in wheat demonstrated that kinetin and auxin significantly increased potassium content in wheat seeds by 16.73% and 10.33%, respectively (Wierzbowska et al., 2007). Conversely, Czapla et al. (2003) reported a 9% reduction in average potassium content in soybean when plants were sprayed with synthetic auxins (IBA and NAA), either separately or together. Furthermore, the application of IBA, BAP, and IBA+BAP in lupin decreased potassium content, particularly in seeds, as a response to all treatments. Another experiment Wierzbowska et al. (2007), showed that plant growth regulators in the form of gibberellin and auxin increased calcium content in wheat grains, stems, husks, and leaves by 28% compared to controls. Thus, the use of growth regulators not only affects plant growth and production (quantity) but also influences crop quality (Wijayati et al., 2005).

The findings of this study also indicated that rhizomes harvested at 8 months had greater weight compared to those harvested at 6 months. This condition can be explained through plant physiological concepts, particularly the storage-filling phase (sink strength), which peaks at 8 months. During this phase, more photosynthates are allocated to storage organs (rhizomes), resulting in greater biomass accumulation (Kurniawan et al., 2021; Muderawan et al., 2022). Hence, harvesting at older plant ages yields larger and heavier rhizomes (Rusmin et al., 2015). In addition, longer harvest duration allows rhizomes to mature more fully, with denser storage tissues that are more stable against physiological changes during storage. This factor is crucial in improving quantitative harvest outcomes (Paz et al., 2005; Panneerselvam et al., 2008).

Beyond yield, harvest age also affects rhizome quality, particularly starch and secondary metabolite content. Starch serves as the main energy reserve, while secondary metabolites such as essential oils and other bioactive compounds act as natural defense mechanisms against degradation and pathogen attack (Policegoudra and Aradhya, 2007; Rusmin et al., 2015). Higher starch and secondary metabolite content in 8-month-old rhizomes has been shown to improve storability, as reflected in lower weight-loss rates compared to younger rhizomes. Therefore, harvesting at 8 months, combined with the application of growth hormones such as auxins and cytokinins, not only enhances productivity but also maintains postharvest quality. This strategy represents a critical step in the cultivation of *K. galanga* and related crops, as it balances both quantitative yield and rhizome quality for consumption and industrial purposes.

CONCLUSIONS

Combined application of NAA and BA significantly improved rhizome weight and storability of Kaempferia galanga. The high-dose treatment (NAA 30 ppm + BA 30 ppm) resulted in the highest rhizome weights at both harvest ages (60.32 g/plant at 6 MAP and 100.9 g/plant at 8 MAP). Weight loss during storage was minimized under this treatment, maintaining 87.73% and 93.25% of initial weight after 30 DAH at 6 MAP and 8 MAP, respectively. Harvesting at 8 MAP was more optimal than at 6 MAP, producing larger rhizomes with superior storability.

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