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Analysis of Vegetative Morphological Characteristics, Yield Potential, and Chemical Composition of Sweet Potato Lines (*Ipomoea batatas* L.) Resulting from Open Pollination with Ayamurasaki Female Parents

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Abstract

Sweet potato (*Ipomoea batatas* L.) is an important food crop in Indonesia with high potential to support food diversification, improve nutrition, and develop functional food products. The purple-fleshed variety (Ayamurasaki) is used as the female parent in breeding programs due to its high anthocyanin content. This study aimed to analyze the vegetative morphological characteristics, yield potential, and chemical composition of open-pollinated sweet potato lines using Ayamurasaki as the female parent. This study was conducted using a Randomized Block Design (RBD) consisting of five lines, namely A19, A23, A39, A74, A84, and the Ayamurasaki variety as a control, with three replications. Observations were made on vegetative morphological parameters, tuber weight per plant, and chemical composition analysis. The results showed significant variations among the tested genotypes for all observed parameters. The A23 line showed superior performance, characterized by larger leaf size, larger stem diameter, high yield, and the highest anthocyanin content. Meanwhile, the A84 line showed potential for industrial use due to its relatively high carbohydrate and starch content. These findings provide valuable information for the further development of superior sweet potato lines with high productivity and better nutritional value to support future breeding programs.

Keywords: Sweet potato; female parent; vegetative morphology; yield potential; anthocyanin.

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is one of the most important food crops in many tropical and subtropical regions, including Indonesia. Sweet potatoes play a strategic role in supporting national food security due to their adaptability, short growth cycle, and ability to produce under low-input farming systems. In addition to being a source of carbohydrates, sweet potatoes contain important nutrients, including dietary fiber, vitamins, minerals, and bioactive compounds, which have functional benefits for human health. Among various sweet potato varieties, purple-fleshed sweet potatoes are gaining increasing attention due to their high anthocyanin content, which functions as a natural antioxidant with antidiabetic, anti-inflammatory, and anticancer properties. Therefore, the development of purple-fleshed sweet potatoes with superior agronomic and nutritional properties is crucial to support food diversification and functional food innovation in Indonesia.

Indonesia remains one of the world's leading sweet potato producers; however, national productivity remains relatively low compared to its potential. Breeding efforts aim to produce genotypes with better yields, better adaptation to diverse agro-ecological conditions, and higher nutritional value. One of the most promising approaches is the use of purple-fleshed varieties with high anthocyanin content as parent lines in breeding programs. Among these varieties, the Japanese cultivar Ayamurasaki has been widely recognized for its deep purple flesh, stable pigmentation, pleasant flavor, and high anthocyanin concentration.

Ayamurasaki is used as a female parent in sweet potato breeding due to its consistent performance in producing offspring with desirable pigmentation and nutritional qualities. Open pollination involving Ayamurasaki and adapted local Indonesian genotypes provides an opportunity to combine advantageous traits, such as high yield potential, vigorous vegetative growth, and high levels of bioactive compounds. However, the variation resulting from open pollination must be systematically evaluated to identify the most promising lines. Initial evaluation generally focuses on vegetative morphological characteristics, as these traits are closely linked to photosynthetic capacity, biomass accumulation, and ultimately storage root formation. Parameters such as stem internode length, leaf size, and stem diameter are considered reliable early indicators of plant vigor and adaptation.

In addition to vegetative characteristics, yield potential remains a key criterion in selecting superior lines. Variations in root weight, shape, size, and number are strongly influenced by genetic and environmental factors, as well as their interactions. Lines with vigorous vegetative growth and efficient assimilate translocation generally exhibit higher yield performance. Furthermore, the chemical composition of storage roots, particularly anthocyanins, water content, and other proximate components, determines the nutritional and functional value of the resulting variety. Purple-fleshed sweet potato lines with high anthocyanin content have high market potential for use in functional foods, natural colorants, nutraceuticals, and the health-based food industry.

Although some breeding efforts have been conducted previously, most research in Indonesia has focused solely on morphological characterization, yield evaluation, or chemical composition. Comprehensive studies integrating all three aspects—vegetative morphology, yield potential, and chemical composition—are still limited, especially for lines derived from open-pollination with Ayamurasaki as the female parent. Integrated evaluation is crucial for identifying promising lines with desirable trait combinations that meet consumer, industrial, and nutritional demands.

Therefore, this study was conducted to analyze the vegetative morphological characteristics, yield potential, and chemical composition of sweet potato lines resulting from open pollination with Ayamurasaki as the female parent. These findings are expected to contribute to the selection of potential superior lines for further breeding and development into high-yielding, nutritious varieties that support food security, functional food innovation, and sustainable agricultural development in Indonesia.

MATERIALS AND METHODS

Study Area

The field trial was conducted at the Lampung State Polytechnic Experimental Garden, Bandar Lampung, Indonesia (80–100 m above sea level), between June and September 2025, representing a tropical monsoon climate zone suitable for sweet potato cultivation. This region experiences an annual temperature range of 15–35°C with a relative humidity of 70–85%, conditions known to support optimal root growth and development of *Ipomoea batatas* L. (Sun et al., 2025). Laboratory analysis of chemical composition, including proximate characteristics and anthocyanin content, was conducted at the GIS Laboratory, Bogor, West Java, an accredited facility equipped for standard biochemical evaluation. The implementation of the field trial in Lampung provides a relevant agroecological representation for the tropical lowland environment, which is one of the main sweet potato production zones in Indonesia (BPS, 2024).

Data Collection

Data collection was conducted to measure vegetative morphological traits, yield performance, and chemical composition of the assessed sweet potato lines. Vegetative morphological data were recorded at 60 days after planting (DAP) from two representative plants per plot following standard sweet potato descriptors, and average values were calculated. Traits measured included stem internode length (cm), stem diameter (mm), leaf length (cm), and leaf width (cm). Yield data were collected at physiological maturity (100–110 DAP) by harvesting two plants per plot and determining the average storage tuber weight per line. For chemical composition, storage tubers from each plot were sampled and transported to the GIS Laboratory, Bogor, West Java, for laboratory analysis. The analysis included proximate composition (ash content, total fat content, water content, total energy, carbohydrate content, protein content, starch content) and anthocyanin content, all measured using standard analytical methods. All data obtained were tabulated and processed for further statistical analysis to determine variation between genotypes.

Data Analysis

All quantitative data obtained from morphological assessments, yield, and chemical composition were statistically analyzed to determine genotype-related variability among sweet potato lines. Analysis of Variance (ANOVA) was performed using a Randomized Block Design (RBD) with genotype as a fixed factor and three replications. Statistical significance was evaluated at $p \leq 0.05$. If a significant effect was detected, post-hoc comparisons of means were performed using the Least Significant Difference (LSD) test at the 5% probability level to identify pairwise differences between genotypes. Chemical composition data were analyzed descriptively and interpreted in relation to the genotypes' nutritional and functional qualities. Results were tabulated and graphically illustrated to facilitate interpretation and discussion. Statistical analyses were performed using standard analytical procedures appropriate for agricultural field experiments.

RESULTS AND DISCUSSION

Vegetative Morphological Characteristics

Table 1. shows that the evaluated sweet potato lines exhibited clear variations in vegetative morphological traits, particularly in leaf size, stem internode length, and stem diameter. These differences indicate genetic variability among the open-pollinated Ayamurasaki progeny, which is expected due to the nature of cross-pollination and the resulting genetic recombination. In this study, Lines A19 and A23 exhibited the most

vigorous vegetative growth, characterized by larger leaf dimensions and thicker stems, whereas Ayamurasaki (the female parent) consistently showed smaller leaf size and relatively less vigorous vegetative growth.

Leaf size is an important determinant of photosynthetic capacity, as wider leaves increase light capture and promote biomass accumulation. The larger leaf area observed in A19 and A23 indicates a higher assimilate production potential, which is essential for optimal root enlargement. Sweet potato genotypes with robust foliage and larger leaf area tend to have greater photosynthate reserves, supporting higher storage root development. The stronger vegetative growth observed in A23 is consistent with its high yield performance, implying efficient conversion of photosynthate into storage roots.

Internode length and stem diameter also varied among genotypes, reflecting differences in growth habits and vigor. The A23 line exhibited a robust stem architecture, which likely contributed to better structural support, efficient assimilate translocation, and increased tolerance to lodging or environmental stress. In contrast, Ayamurasaki maintained shorter internodes and moderate stem thickness, consistent with its known phenotype of intense pigmentation but moderate biomass productivity. This observation aligns with a report by Setoguchi et al. (2023), which noted that purple-fleshed sweet potato varieties often allocate more resources to secondary metabolites, such as anthocyanins, than to vegetative biomass.

From a practical perspective, vigorous vegetative traits are desirable to farmers because they increase canopy coverage, reduce weed pressure, and support higher yield potential. Lines such as A23 and A19, which exhibit broad leaf surfaces and sturdy stems, are therefore promising candidates for on-farm cultivation, especially in low-input systems where natural weed competition is advantageous.

Overall, the morphological trait variations observed in this study confirm that open-pollinated Ayamurasaki offspring exhibit diverse phenotypes, some of which exhibit superior vegetative vigor compared to the female parent. These morphological differences serve as early indicators of yield potential and agronomic performance, and can be used as selection criteria in early-generation sweet potato breeding.

Table 1. Average Vegetative Morphological Characteristics of Purple Sweet Potato Lines from Open Pollination with Ayamurasaki as the Female Parent.

Line	Internode Length (cm)		Leaf Length (cm)		Leaf Width (cm)		Stem Diameter (mm)	
A19	4.67	a	11.00	a	10.67	a	5.13	a
A23	4.75	a	10.75	a	8.67	b	4.58	ab
A39	4.17	a	8.83	b	8.20	bc	4.50	ab
A74	4.25	a	8.72	b	7.63	bc	4.07	bc
A84	4.58	a	7.12	c	7.02	c	3.60	cd
Ayamurasaki	4.30	a	6.33	c	6.83	c	3.17	d

Potential Harvest Yield

Table 2. The yield potential of the evaluated sweet potato lines showed distinct variation, confirming genetic diversity among the open-pollinated progeny of Ayamurasaki. Yield is known to be a complex trait influenced by genotype, resource-sink dynamics, assimilation and allocation, and genotype-by-environment interactions. In this study, Line A23 showed the highest yield performance, followed by A84 and Ayamurasaki, while A74, A19, and A39 produced relatively lower yields. These results indicate that some progeny successfully inherited favorable yield-enhancing traits from their male parent, thus enabling them to surpass the performance of the female parent, Ayamurasaki.

The superior yield achieved by A23 is largely attributable to its vigorous vegetative growth, particularly its large leaf area and robust stem development, which enable greater capture of sunlight, thereby increasing photosynthetic efficiency and total biomass accumulation. Genotypes with high source capacity (photosynthate production) tend to exhibit stronger sink development in the form of enlarged storage roots when the source-sink balance is well maintained. Recent studies have shown that sweet potato lines with robust foliage and efficient canopy photosynthesis exhibit increased storage root filling and yield potential (Liang et al., 2024). Thus, the high-yielding performance of A23 may be attributed to efficient assimilate production and effective translocation to storage roots.

A84 and Ayamurasaki showed moderate yield performance, indicating stable adaptability under the agro-climatic conditions of the study site in Lampung, a region recognized as one of the potential sweet potato development zones in Indonesia. Nationally, sweet potato productivity in Indonesia has shown gradual increases, supported by the introduction of superior genotypes and the expansion of regional cultivation centers (Balitkabi, 2022). Ayamurasaki's yield, although not the highest, aligns with its known characteristics that prioritize anthocyanin accumulation, which often result in moderate root biomass. This observation is consistent with recent findings reporting that purple-fleshed genotypes tend to allocate more metabolic resources to secondary metabolite synthesis, which may limit maximum yield potential (Herms, D. A., & Mattson, W. J., 1992).

On the other hand, lines with lower yields—A74, A19, and A39—may experience less efficient source-sink coordination. Although A19 exhibits vigorous leaf growth, the imbalance between excessive vegetative growth and limited storage root development suggests that vegetative vigor alone is not a direct predictor of high yields. Sweet potato yield depends on the plant's ability to channel assimilates to storage roots rather than sustaining long-term vine growth. This concept is supported by research showing that genotypes with disproportionate vine biomass often exhibit reduced root enlargement due to competition for assimilate allocation (Pazos et al., 2021). The results for A19 reinforce this principle, demonstrating the importance of balanced growth for optimal yield.

From a practical perspective, high-yielding varieties like A23 offer farmers promising opportunities because they can increase productivity per unit of land, thereby enhancing farm profitability and local food supply. Meanwhile, genotypes like A84 and Ayamurasaki, which combine moderate yields with desirable nutritional and functional traits, offer strong prospects for niche markets, including the functional food and health-oriented product industries. These markets value anthocyanin richness, consumer appeal, and product differentiation over maximum yield, making these varieties attractive for agro-industrial development.

Overall, the observed yield variation in this study highlights the value of open pollination as a breeding approach for producing diverse offspring with improved traits. A23 emerged as a promising candidate for further development into multi-location trials to verify yield stability across diverse environments, while A84 and Ayamurasaki showed potential for value-added product development. These findings provide important guidance for the selection and breeding of sustainable sweet potato varieties that meet market-driven productivity and quality demands.

Table 2. Average Storage Weight of Purple Sweet Potato Tubers Resulting from Open Pollination with Ayamurasaki as the Female Parent

Line	Average Weight of Storeable Roots (kg)
A19	0.5
A23	1.5
A39	0.5
A74	0.9
A84	1
Ayamurasaki	1

Chemical Composition

Chemical content analysis was conducted to determine the nutritional value and functional potential of purple sweet potato lines resulting from free crosses with Ayamurasaki parents. Parameters observed included ash content, total fat, water, total energy, carbohydrate, protein, starch, and anthocyanin content. Evaluation of this chemical composition is important because it not only determines basic nutritional quality but also illustrates the potential of sweet potatoes as a functional food rich in bioactive compounds. The results of observations on the chemical content of several sweet potato lines are presented in the Figure 1.

Chemical analysis of several purple sweet potato lines from free-crossing with Ayamurasaki parents showed variation among lines in various parameters, including ash content, total fat content, water content, total energy, carbohydrates, protein, starch, and anthocyanin (Figure 1). This variation reflects the genetic diversity inherited from the Ayamurasaki female parent and the male lines used in free-crossing.

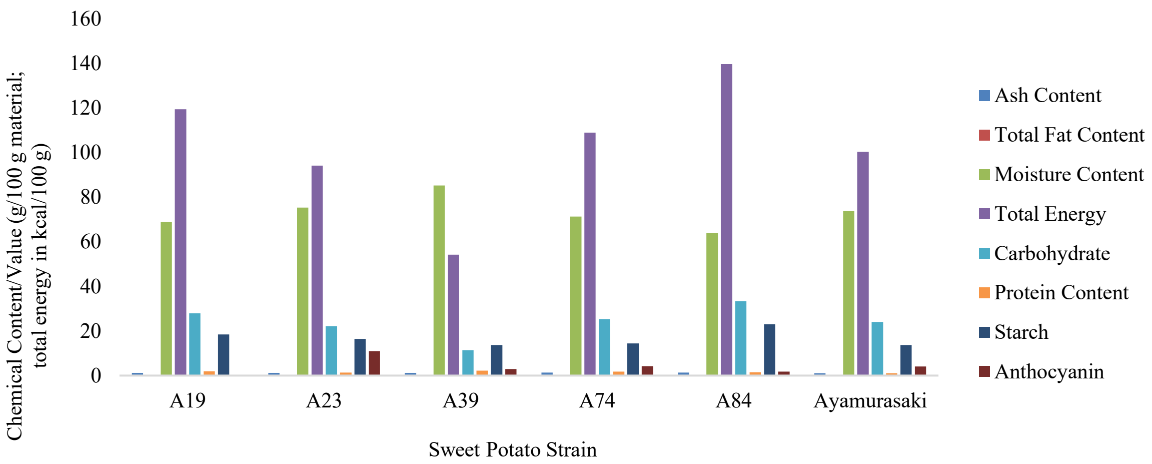

Figure 1. Graph Average Chemical Composition of Several Purple Sweet Potato Strains Derived from Open Pollination with the Parent Ayamurasaki.

The ash content of the tested lines ranged from 1.13% to 1.42%, with the highest in the A74 line (1.42%) and the lowest in the Ayamurasaki line (1.13%). Ash content indicates the amount of minerals in the material, so the higher ash content in the A74 line suggests a greater potential as a mineral source. Research by Oliveira et al. (2017) reported that the mineral composition of sweet potatoes, including ash content, is highly dependent on soil fertility and the availability of micronutrients such as Fe, Zn, and Ca. Furthermore, Tenguria et al. (2024), noted that differences in ash content can also be caused by variations in varieties and growing environments, which influence nutrient absorption efficiency through the root system. Therefore, variations in ash content across crossbred lines reflect physiological diversity in adaptability to land conditions and soil nutrient availability.

The total fat content of all strains was very low (<0.02%), consistent with sweet potatoes' physiological characteristics as a low-fat food. This low-fat content makes sweet potatoes a healthy food choice and supports the trend in modern society toward balanced nutrition and low cholesterol. Research by Mu & Zhang (2019), reported that sweet potato tubers naturally contain less than 0.1% total fat, mainly composed of relatively small unsaturated fatty acids, which play an important role in energy metabolism. Additionally, the FAO (2023) highlighted that sweet potatoes are a food commodity with a low glycemic index and minimal fat, making them highly suitable for development as raw materials for functional foods and healthy diet products.

Water content varied significantly, ranging from 63.76% (A84) to 85.16% (A39). High water content is associated with a softer tuber texture, whereas low water content results in a drier texture (masir). According to Zakka et al. (2025), water content is a key factor influencing the shelf life and quality of processed sweet potatoes. Therefore, the A84 line, with its lower water content, has greater potential for processing into dry food products with longer shelf lives.

The total energy produced by sweet potato strains also varies, from the lowest 54.24 kcal (A39) to the highest 139.68 kcal (A84). This value indicates a difference in carbohydrate content between lines, as carbohydrates are the largest contributor of energy. A84 has the highest total energy (139.68 kcal), which is consistent with its carbohydrate content (33.44%), whereas A39 has low energy due to its low carbohydrate content (11.41%). This finding is consistent with a recent report indicating that the energy content of sweet potatoes (*Ipomoea batatas* L.) is strongly influenced by the levels of starch and carbohydrates stored in the tubers (Vital et al., 2023). Starch is the main energy source, while simple carbohydrates such as glucose and sucrose determine the tubers' sweetness and nutritional value. In addition, Khatefov et al. (2023) reported that variations in starch content among genotypes can lead to significant differences in total energy values, making this chemical character important in selecting superior lines for food and industrial applications.

Protein content in crossbred sweet potato lines ranges from 1.02% to 2.15%. The A39 line had the highest protein content (2.15%), while Ayamurasaki showed the lowest (1.02%). These results align with the findings of Zhao et al. (2024), who noted that sweet potato protein content is generally low. However, there is variation among genotypes due to genetic and environmental factors. Although sweet potato (*Ipomoea batatas* L.) is not a primary source of protein, higher-protein varieties still contribute nutritional value, especially for communities with limited access to animal protein (Umezaki et al., 2001). Therefore, increasing protein content through breeding programs can be a promising approach for developing superior sweet potato lines with enhanced nutritional value.

Starch content varied among strains, ranging from 13.7% (A39) to 23.02% (A84). The A84 strain has the highest starch content, aligning with its carbohydrate and total energy levels. This makes A84 a potential raw material for the sweet potato flour industry. Conversely, A39 has a lower starch content, making it more suitable for fresh consumption or processed foods that do not require high starch levels.

Anthocyanin levels, an important parameter in purple sweet potatoes, also vary between strains. Ayamurasaki, the parent strain, contains 4.1 mg/100 g, while crosses show a wider range. The A23 strain has the highest anthocyanin content (10.92 mg/100 g), far surpassing that of Ayamurasaki, while A84 has the lowest content (1.84 mg/100 g). High anthocyanin content adds functional value to sweet potatoes because it acts as a natural antioxidant that can protect cells from free-radical damage. The antioxidant activity of anthocyanins in sweet potatoes (*Ipomoea batatas* L.) is crucial for preventing degenerative diseases and improving metabolic health (Awan et al., 2023). This shows that independent crosses can produce strains with higher bioactive compounds than their parents, offering great potential for development as functional foods.

Anthocyanins contribute to the characteristic purple pigmentation and have strong antioxidant activity, which has been linked to a lower risk of non-communicable diseases, including diabetes, cardiovascular disorders, and inflammation (Yang et al., 2025). In Indonesia, demand for anthocyanin-rich crops has grown along with increased consumer awareness of functional foods. National research also emphasizes purple-fleshed sweet potatoes as a promising source of antioxidants and natural colorants for the food, beverage, and nutraceutical industries (Lucas et al., 2025). Therefore, strains with high anthocyanin levels show great potential for developing value-added products for health-focused food applications.

From a biochemical perspective, anthocyanin variation among lines can be attributed to differential expression of genes involved in flavonoid biosynthesis.

Environmental adaptation and genotype-specific regulatory mechanisms also influence anthocyanin accumulation in storage tubers (Wang et al., 2025). The strong anthocyanin expression in the selected lines suggests that favorable alleles associated with pigmentation are successfully inherited from the male parent during open pollination, thus enabling the development of offspring with improved functional qualities.

Anthocyanin content is a crucial quality trait in purple-fleshed sweet potatoes because of their known functional properties and health advantages. The results showed notable variation in anthocyanin levels among the evaluated lines, with some offspring displaying higher levels than those of Ayamurasaki, the female parent.

CONCLUSION

This study provides an integrated understanding of the morphological characteristics, yield performance, and chemical composition of sweet potato (*Ipomoea batatas* L.) lines produced by open pollination using Ayamurasaki as the female parent. The findings indicate that open pollination yields substantial phenotypic and biochemical diversity among progeny, offering valuable opportunities for selecting and breeding superior genotypes.

Overall, the results showed that the A23 line exhibited the most desirable combination of traits, including vigorous vegetative growth, efficient source-sink balance, and high yield potential. These attributes reflect increased photosynthetic capacity, effective assimilate translocation, and a positive root formation response, suggesting that A23 is well-positioned as a candidate for further development in the breeding pipeline. Meanwhile, A84 and Ayamurasaki showed moderate yield performance but superior chemical quality, particularly in anthocyanin accumulation. These traits highlight their potential for high-value functional food applications rather than solely yield-driven production. The variability detected across lines reinforces the importance of integrating multi-trait evaluation in early-generation selection to better capture genotype performance beyond single-trait assessment.

From an evaluative standpoint, this study enhances understanding of how morphological traits correlate with agronomic and biochemical outcomes. The integration of three trait domains—morphology, yield, and chemical composition shows that genetic expression from open pollination can either strengthen or weaken parental-specific qualities. This emphasizes the need for balanced selection criteria to prevent favoring one trait at the expense of others. The study also stresses the importance of aligning genotype potential with market-driven product pathways, recognizing that "superior" performance is context-dependent: high yields can benefit producers, while high anthocyanin content benefits processors and the functional food industry.

Despite these important insights, this study also acknowledges several limitations that warrant attention in future research. The evaluation was conducted at a single location and during one growing season, which limits the ability to assess genotype × environment interactions and yield stability across different agroecological zones. Additionally, the chemical analysis was limited to reducing sugars and anthocyanins. A more comprehensive nutritional profile, including starch, fiber, mineral content, and antioxidant capacity, could provide a fuller assessment of market value. Nonetheless, this study has established a solid baseline data set that can guide future breeding and product development efforts.

These findings collectively indicate that the future of sweet potato development depends on strategically merging agronomic performance with functional quality traits to remain competitive in both food security and value-added markets. Therefore, these research results emphasize the importance of using open-pollinated progeny as a valuable source of genetic diversity for breeding programs designed to meet the changing needs of farmers, consumers, and the agro-industry.

Competing Interests: The authors declare no conflict of interest.

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