Jurnal Ilmu Pertanian Indonesia (JIPI), October 2025
(Indonesian Journal of Agricultural Sciences)
ISSN 0853-4217 EISSN 2443-3462

Vol. 30 (4): 712–717
http://journal.ipb.ac.id/index.php/JIPI
DOI: 10.18343/jipi.30.4.712

Agronomic Characteristics of Three Introduced Genotypes of Kailan Plants in Tropical Lowlands

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(Received December 2024/Accepted June 2025)

ABSTRACT

Kailan has strong selling power, making it an attractive commodity for farmers. Plant introduction in a breeding program is one of the attempts being made to boost commercial kailan yield in Indonesia. The purpose of this introduction was to develop new varieties with high production, good yield quality, resistance to plant pest assaults, and adaptation in a variety of situations. The study sought to assess the agronomic properties of several imported kailan genotypes when grown in tropical lowlands. This experiment was conducted from May to July 2023 in the experimental field of the Faculty of Agriculture at Universitas Muhammadiyah Jakarta, South Tangerang City. The study employed a Randomized Complete Block Design with one treatment factor, the kailan genotype, with five levels, including three introduced genotypes (KI001, KI002, and KI003) and two national varieties as comparators (Nita and Nemo). The results revealed that the introduced genotype KI003 had superior total fresh weight and marketable fresh weight features than the other introduced genotypes and all comparator varieties. The introduced genotypes KI001 and KI002 share the same agronomic features as the two comparator varieties. The study found that all introduced varieties could adapt well to lowland tropical climatic conditions, however only the introduced genotype KI003 demonstrated superior adaptation when compared to the comparator types.

Keywords: Brassica *oleracea* L, genetic variation, plant breeding, plant introduction

INTRODUCTION

Kailan (*Brassica oleracea* L.), a leafy vegetable from the Brassicaceae family, is a favorite choice among the population. It has thicker leaves, a sweeter taste, and a more tender texture than other cruciferous vegetables. Because of its similarities to broccoli and kale, this vegetable is also known as Chinese kale, Chinese broccoli, or white flowering broccoli (Permatasari and Herlina 2018). Kailan has a particularly high nutritional content. According to Oktaviani and Sholihah (2018), 100 g of raw kailan contains 3500 IU of vitamin A, 0.11 mg of vitamin B1, 90 g of water, 3.6 g of fat, 1.6 mg of niacin, 78.0 mg of calcium, 1.0 mg of iron, 38.0 mg of magnesium, and 74.0 mg of phosphorus. Furthermore, Samadi (2013) noted that kailan includes carotenoids that are useful in cancer treatment, a good supply of iron, which is essential for human health. Although kailan is a unique vegetable with enormous market potential in Indonesia, farmers' cultivation of it is restricted. The production of cruciferous vegetables, especially kailan, has fluctuated. According to the Central Bureau of Statistics, kailan production reached 1.43 million tons in 2021, rose to 1.50 million tons in 2022, and then fell to 1.40 million tons in 2023 (BPS 2024). As a result, improving kailan production is critical to meeting the market's ever-increasing demand.

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Plant introduction as part of a breeding program can be used to further the commercial development and productivity of kailan in Indonesia. The goal of this method is to create new varieties that are high in productivity, have good fruit quality, are resistant to pests and diseases, and are adaptable to a wide range of environmental conditions. Currently, kailan varietal development is national in scope and not agroclimatically specific. Furthermore, introductions from subtropical regions into Indonesia have been limited to the highlands, resulting in inadequate kailan productivity. As a result, the creation of new better cultivars is critical to allowing kailan to grow optimally with high yield, pest and disease resistance, and adaptability to both lowland and highland settings throughout Indonesia.

Potential genotypes face the difficulty of uneven yields when grown in different conditions. To solve this, evaluation is a critical step in determining varietal traits, yield capacity, and quality. This evaluation must consider the real cultivation environment (Nazirwan *et al*. 2014). Sumiahadi *et al*. (2024) found that imported lettuce plants have distinct growth and physical traits. This knowledge is critical for plant breeding and the production of improved lettuce types. Based on the, attempts to improve the genetic resources of horticultural commodities are required for producing superior kailan varieties, with introduction being one example. This study anticipates that the inserted kailan genotypes will increase genetic variety and emerge as prospective lines. These lines can be used as ready-to-cultivate superior varieties or as valuable genetic material for future kailan breeding efforts. The purpose of this study was to assess the agronomic properties of various introduced kailan genotypes when grown in tropical lowlands.

METHODS

Research Location

This study was conducted from May to July 2023 on the experimental field of the Faculty of Agriculture, Universitas Muhammadiyah Jakarta. The location is in Cirendeu, Ciputat Timur, South Tangerang City, at coordinates 6°17'58" S and 106°46'02" E, with an elevation of around 15 m above sea level. The soil in this site is Latosol (BPS Kota Tangerang Selatan 2019). Table 1 details the climatic data collected during the investigation.

Materials and Tools

The study's components included soil, rice husk charcoal, plastic mulch, goat dung, labels, urea, seeds from three introduced kailan genotypes, and seeds from two national kailan varieties (Nita and Nemo). Tools used included hoes, seedling trays, hand sprayers, watering cans, calipers, rulers, an analytical balance, yellow traps, and a camera.

Experimental Design

The study used a Randomized Complete Block Design (RCBD) with a single treatment element, the kailan genotype. Five treatment levels were constructed, with three introduced genotypes (KI001, KI002, and KI003) and two national varieties (Nita and Nemo) serving as comparators. Each treatment was reproduced five times, yielding a total of 25 experimental units. Each experimental unit was defined as a 0.6 m × 0.6 m area that could accommodate 9 plants. Three plants from each experimental unit were sampled, for a total of 75 samples.

Research Implementation

The kailan seeds were sown in an organic growing medium consisting of soil and farmyard manure in a 2:1 ratio. Following homogenization, the media was transferred to seedling trays. A water immersion test was used to check seed viability, and only seeds that sank were planted. Then, a single viable seed was delicately placed into each cell of the prepared seedling trays.

Land preparation activities began three weeks before planting. Tilling, weed and plant waste clearance, soil leveling, and raised bed plot construction were among the operations performed (Ali *et al*. 2022). The created plots measured 0.6 m × 0.6 m and had an inter-plot interval of 0.4 m. One week before planting, 15 tons of goat dung (or 375 g per plot) was treated as a base fertilizer (Samadi 2013). Two weeks after planting, urea inorganic fertilizer was applied at 130 kg ha^{-1} (or 0.8125 g $plant^{-1}$) using a subsurface incorporation method (Ali *et al*. 2022).

Plastic mulch installation entailed fastening the right and left sides of the mulch with 20−25 cm bamboo splits. The mulch was carefully put to completely cover the raised bed surface, eliminating wind-induced shredding or detachment. Planting took place at a 20 cm × 20 cm spacing, with one seedling in each hole. Planting density was set at 20 cm × 20 cm, with one seedling in each planting hole. Crop management strategies included irrigation, hand weeding, and insect control. Weed management was mechanical, however pest control was entirely manual, as pest infestations were modest and had little effect on the kailan plant. To prevent pest assaults, refugia plants (sunflowers) were planted, and yellow traps were set when the kailan plants were placed into the beds. Kailan plants were harvested 42 days after transplantation. The harvesting procedure entailed gently uprooting the entire kailan plant, which was then thoroughly cleaned with clean water.

Observations and Data Analysis

Several characteristics were measured, including plant height, number of leaves, leaf length, leaf breadth, stem diameter, root length, root fresh weight, total fresh weight, and marketable fresh weight. To determine treatment effects, the gathered data were analyzed using SAS 9.1 with an F-test (ANOVA). For ANOVA results that revealed a significant effect, Tukey's Honestly Significant Difference (HSD) test was used at the 5% significance level.

RESULTS AND DISCUSSION

Several variables were examined, including plant height, number of leaves, leaf length, leaf width, stem

Table 1 Climatological data at study site from May to July 2023

Month	Average temperature (C)	Average humidity (%)	Total rainfall (mm $month^{-1}$)	Maximum light period (h day^{-1})
May	29.36	82.13	90.80	9.50
June	28.80	82.50	124.90	10.10
July	28.24	80.58	53.50	10.50

Source: BMKG 2023.

diameter, root length, root fresh weight, total fresh weight, and marketable fresh weight. To investigate the treatment effects, the data gathered were analyzed using SAS 9.1 with an F-test (ANOVA). For ANOVA results with a significant effect, a Tukey's HSD test at the 5% significance level was used. In terms of leaf number and stem diameter, the introduced genotype KI003 produced the most leaves and greatest diameter, which were not statistically different from the Nemo variety but significantly better than the Nita. The introduced genotypes KI001 and KI002 showed no significant difference in leaf number or stem diameter when compared to the two comparator cultivars. Overall, these findings show that all introduced genotypes were capable of effective photosynthesis, resulting in leaf numbers that were not statistically different from the comparator variety (Table 2).

Introduced genotype KI003 had the longest leaves, with no significant difference from introduced genotype KI001 or the comparator types (Nita and Nemo). In contrast, the introduced genotype KI002 exhibited leaf lengths that were not statistically different from the variation Nemo but shorter than the variety Nita. In terms of leaf width, the introduced genotype KI003 produced the widest leaves, which differed considerably from all comparator kinds tested. In contrast, the introduced genotypes KI001 and KI002 showed no significant difference in leaf width from the comparator variety (Table 2).

Based on our observations, the introduced genotype KI002 had the longest roots, which were comparable to introduced genotype KI003 and other comparator kinds. In contrast, the introduced genotype KI001 had the lowest root length, although it did not differ significantly from Nita and Nemo. The introduced genotype KI003 had the heaviest root fresh weight, which was not statistically different from the variety Nemo but significantly heavier than the introduced genotypes KI001, KI002, and Nita. The introduced genotypes KI001 and KI002 had root fresh weights that were not statistically different from the variety Nita but significantly lower than the variety Nemo (Table 3). It also reveals that KI003 yielded the highest total fresh weight and marketable fresh weight. These values differed significantly from other introduced genotypes and all comparative cultivars. Meanwhile, KI001 and KI002 produced total and marketable fresh weights that were not statistically different from those of the comparator variety.

In general, introduced kailan varieties may adapt well to tropical settings, as evidenced by growth rates equivalent to, or even better than, comparator varieties (Figure 1). When compared to genotypes KI001 and KI002, as well as the comparator cultivars, KI003 exhibits higher growth in terms of plant height, total fresh weight, and marketable fresh weight. This also shows that KI003 is more adaptable than the other introduced genotypes. Each genotype has a unique potential for phenotypic expression based on its intrinsic genetic features. Under optimal environmental conditions, each genotype can fully manifest its phenotypic potential. This study supports Lubis' (2017) claim that the robustness and individual growth of each variety differ depending on its climatic origin; these growth differences stem from both genetic factors and the plant's adaptive capacity to its growing environment. Indicators of a plant's adaptive ability can be observed throughout its vegetative phase, from initiation to completion.

Table 2 Plant height, number of leaves, leaf length, leaf width, and stem diameter of introduced kailan genotypes and comparator varieties

Variety	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	Stem diameter (cm)
Introduced genotype KI001	16.15 ab	10.23 a	16.89 b	15.35 bc	1.37 ab
Introduced genotype KI002	16.20 ab	11.03 ab	13.04 a	11.83 a	1.55 ab
Introduced genotype KI003	22.76 c	11.87 b	18.32 b	17.58 c	1.60 b
National variety Nita	20.82 bc	9.73 a	18.26 b	12.68 ab	1.23 a
National variety Nemo	13.31 a	10.60 ab	16.43 ab	14.13 ab	1.31 ab

Remarks: Numbers followed by the same letters in the same column are not significantly different according to Tukey test at a 5% significance level.

Table 3 Root length, root fresh weight, total fresh weight, and marketable fresh weight of introduced kailan genotypes and comparator varieties

Variety	Root length (cm)	Root fresh weight (g)	Total fresh weight (g)	Marketable fresh weight (g)
Introduced genotype KI001	17.83 a	3.22 ab	72.15 a	52.38 a
Introduced genotype KI002	22.54 b	4.06 ab	61.69 a	44.20 a
Introduced genotype KI003	21.10 ab	5.28 c	123.90 b	87.10 b
National variety Nita	18.63 ab	3.06 a	63.57 a	41.93 a
National variety Nemo	21.12 ab	5.07 c	80.20 a	50.30 a

Remarks: Numbers followed by the same letters in the same column are not significantly different according to Tukey test at a 5% significance level.

Figure 1 Performance of kailan plants: a. Introduced genotype KI001; b. Introduced genotype KI002; c. Introduced genotype KI003; d. Nita Variety; e. Nemo Variety.

Plant development characteristics are affected by two key factors: genetics and environment. According to Syahputri *et al*. (2018), optimal plant growth is heavily influenced by genetic factors, growing conditions, and cultivation strategies. Furthermore, Oktaviani *et al*. (2020) stated that each variety has genetic distinctions that influence growth, yield, and adaptation capacity. Good plant adaptation to the environment promotes good genetic expression. This is consistent with Akbar *et al*. (2014), who argue that environmental conditions affect how plants exhibit their genetic potential. Dachlan *et al*. (2013) earlier stated that phenotypic differences are controlled by both plant genes and environmental factors such as temperature, soil, humidity, and others; the genetic diversity within each variety will manifest in varying characteristics. The environment plays a crucial role in bringing out these genetic traits, meaning even similar plant types can exhibit distinct features.

Crop yield is directly influenced by genotype and variety. Observations demonstrated a favorable relationship between vegetative characteristics (such as plant height, number of leaves, leaf length and width, and stem diameter) and both total and marketable fresh weight of kailan. This means that genotypes or varieties with superior vegetative growth will produce more biomass than previously introduced genotypes and varieties. This discovery is reinforced by Helal *et al*. (2016), that each variety or strain reacts differently to its surroundings at each stage of growth, branching, and leaf development, influencing production. Rajak *et al*. (2016) went on to say that the quantity and area of leaves increase as plant tissues expand and develop, increasing plant weight. These results are also consistent with Pramitasari *et al.* findings (2016) on kailan, which demonstrated that an increase in plant height and leaf area is directly proportional to an increase in marketable fresh weight.

Plant types with high yields are frequently associated with their ability to quickly adapt to changing environmental circumstances. Varieties with higher genetic potential but that require lengthy adaptation periods, on the other hand, tend to produce suboptimal yields (Hayati *et al*. 2012). Sinaga *et al*. (2015) investigated the performance of numerous green mustard genotypes in Brastagi highlands, North Sumatra, during the dry season. This study evaluated three green mustard genotypes (LV-5363, LV-5353, and LV-145) from Balitsa to two commercial kinds (Christina and Green Pakcoy). The results showed that green mustard genotypes LV-5353 and LV-145 exceeded the comparator varieties in terms of yield potential, indicating that they should be developed as new varieties. Sumiahadi and Adiwijaya (2023) found that three new cucumber varieties from Turkey exhibited similar growth characteristics to comparator cultivars but had lower yield components. These imported cucumber plants grew and yielded less than their potential, showing a response to environmental conditions that differed from their natural habitat. This work adds to Saragih *et al*. (2018)'s prior findings, which showed that each plant genotype has distinct growth characteristics due to genetic trait differences and the plant's genetic response to the environment.

For qualitative qualities (leaf shape and color), firsthand observations were made using the UPOV (2003) descriptor. The results indicated that KI001 and Nemo generated green leaves, KI002 had dark green foliage, whilst Nita had green leaves with a waxy texture on the surface. Surprisingly, the leaf color of KI003 diverged significantly from the dark green specified on the seed packing, turning green at harvest. According to UPOV (2003) criteria, three different leaf shapes were observed: narrow obovate, narrow elliptic, and broad obovate. The introduced KI001 had a thin obovate leaf form. The imported genotypes KI002 and KI003 had the same broad obovate leaf form as Nemo, however Nita had a narrow elliptic leaf shape (Figure 2). Plant appearance is shaped by three primary factors: genetics, environmental conditions, and the interaction between genetics and the environment (Syukur *et al.* 2015).

Looking at leaf morphology (Figure 2), there was a noticeable physical distinction in leaf shape. Nita had elongated, uniformly undulated leaves, whereas imported genotypes KI001, KI002, KI003, and Nemo had rounder, wavy leaves. Kailan genotypes KI001, KI002, KI003, and the variety Nemo all have leaflets. Only KI002 had leaflets that did not differ from the main leaf. Furthermore, KI001, KI003, and Nemo had detached leaflets, whereas Nita lacked them totally.

Each genotype has unique quantitative and qualitative traits. Gunawan *et al*. (2019) investigated the morphological and yield potential of 15 mustard

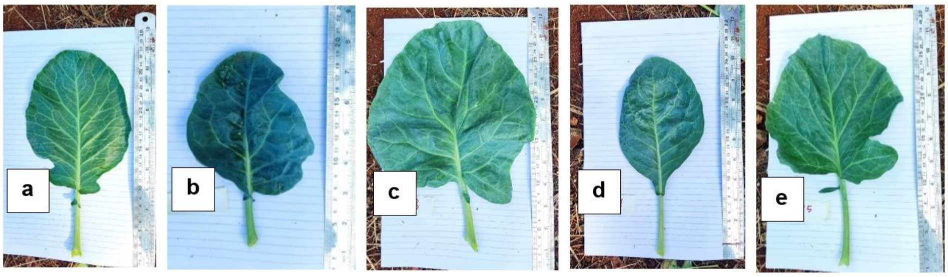

Figure 2 Leaf shape of kailan plants: a. Introduced genotype KI001; b. Introduced genotype KI002; c. Introduced genotype KI003; d. Nita Variety; e. Nemo Variety

genotypes (*Brassica rapa* L.). This includes ten original genotypes (BRP 004, BRP 002, BRP 009, BRP 022, BRP 007, BRP 020, BRP 010, BRP 012, and BRP 021) and five irradiation-induced mutations (BRP 004 R, BRP 002 R, BRP 009 R, BRP 003 R, and BRP 019 R). The study found significant changes in leaf color and blade form between different genotypes. Notably, the irradiated genotypes showed numerous color variants, including BRP 002 R (light green and green), BRP 009 R (light green, green, and dark green), and BRP 019 R (light green and dark green). A study by Sumiahadi *et al.* (2024) revealed that lettuce varieties exhibited differences in both qualitative and quantitative characteristics. Only one of the three introduced varieties (V4) shared similar qualitative traits with the comparator variety. For quantitative characteristics, two varieties (V4 and V5) were similar to the comparator, while another variety (V3) was markedly different. The phenotypic diversity observed in these introduced varieties indicates their substantial potential as a genetic resource for lettuce breeding programs.

This study suggests that the introduced variety KI003 has a larger production potential than the other genotypes and varieties employed in the study. The results also show that the new genotype KI003 has the best adaptability to tropical lowland settings, outperforming the two comparator types (Nita and Nemo). These findings further indicate that the introduced KI003 is appropriate for cultivation in tropical lowlands and has the potential to become a certified lowland kailan variety.

CONCLUSION

The introduced genotype KI003 outperformed the other introduced genotypes and the two national comparator varieties(Nita and Nemo) in terms of total fresh weight and marketable fresh weight. However, the introduced genotypes KI001 and KI002 exhibited agronomic traits that were equivalent to the national comparator cultivars. In general, all introduced genotypes were as adaptable as the comparator cultivars; however, genotype KI003 adapted the best to the tropical lowland environment.

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