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Forage Production Characteristics of Japanese Papaya *(Cnidoscolus aconitifolius*) as Ruminant Feed

Ahmad Hadin Husnassabil
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Marjuki
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Tri Eko Susilorini
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Kuswati
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Puguh Surjowadojo
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Asri Nurul Huda
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Aprillia Ika Putri
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Tifany Sonia Gani
Department of Animal Science, Faculty of Animal Science, Brawijaya University

Address: Veteran Street, Malang City, East Java
Corresponding author: marjuki@ub.ac.id

Abstract. *This study aimed to evaluate the forage production characteristics of Japanese papaya (Cnidoscolus aconitifolius) as a potential feed source for ruminant livestock. The research employed a case study approach through direct field observations on four mature Japanese papaya plants naturally grown as living fences in Malang City. Measured variables included the diameter of the main branch, number and length of sub-branches, forage yield, and nutrient composition. Data were analyzed using correlation and simple linear regression to determine the relationship between plant structure and forage productivity. The results indicated that the diameter of the main branch showed a strong positive correlation with the number and length of sub-branches, as well as with forage yield and nutrient content (DM, OM, CP, CF, and EE). Regression analysis confirmed that larger branch diameters were consistently associated with higher forage production and better nutrient values. These findings suggest that the diameter of the main branch can serve as a reliable indicator for estimating the forage yield and nutritional potential of Japanese papaya, providing a practical tool for its use in sustainable ruminant feed management.*

Keywords: *Cnidoscolus aconitifolius, Forage yield, Nutrient composition, Plant morphology, Ruminant nutrition*

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*Corresponding author, e-mail address *marjuki@ub.ac.id*

INTRODUCTION

Forage plays a vital role in ruminant nutrition as the primary source of energy, protein, vitamins, and minerals (Anggraini and Yulianto, 2023). Ideally, ruminants require forage equivalent to 10% of their body weight daily (Abdillah et al., 2021). However, in tropical regions, forage availability fluctuates greatly with the seasons—abundant during the rainy season but severely limited during the dry period (Muchlis et al., 2023). This fluctuation often leads farmers to rely on commercial concentrate feed to meet nutritional needs (Rahalus et al., 2014). Although concentrates are rich in nutrients and highly digestible (Siliwangi et al., 2022), their high cost makes them economically unsustainable for smallholder farmers (Marhamah et al., 2019).

An effective solution to this problem is the development of green concentrates—feed resources derived from local forages with high nutritional value (Sukri et al., 2019). Among potential candidates, Japanese papaya (*Cnidoscolus aconitifolius*) stands out due to its fast growth, high adaptability, and substantial leaf biomass production (Wonghor and Khonyoung, 2022). The plant also contains a balanced nutrient profile, with moderate protein and fiber levels suitable for ruminant diets (Sudartini et al., 2019). Moreover, it can grow on marginal land with minimal input, offering an eco-friendly and low-cost feed alternative. Although the leaves contain anti-nutritional compounds such as oxalates and phytic acid (Babalola and Alabi, 2015), these can be reduced through simple processing methods like drying or wilting (Ramteke et al., 2019).

Despite its potential, research on the relationship between plant morphology and forage productivity of Japanese papaya remains limited. Understanding how morphological traits—such as the diameter of the main branch, number and length of sub-branches—relate to yield and nutrient content is crucial for estimating its forage production potential (Rustani and Susanto, 2019; Novianti and Setiawan, 2018).

Therefore, this study aims to evaluate the correlation and regression between the main branch diameter and forage production characteristics of Japanese papaya, including sub-branch number and length, forage yield, and nutrient composition. The findings are expected to provide a novel reference for using Japanese papaya as a sustainable green concentrate source in ruminant feed management under tropical conditions.

LITERATURE REVIEW

The Japanese papaya (*Cnidoscolus aconitifolius*) is a perennial shrub characterized by woody stems, numerous branches, rapid growth, and large leaves. Native to the Yucatán Peninsula of Mexico, Central America, this plant—commonly known as "Chaya"—was historically a staple food of the Maya civilization (Kuri-García et al., 2017). It belongs to the family Euphorbiaceae, is easy to cultivate, and exhibits strong resistance to pests and diseases (Padilla-Camberos et al., 2021). Although originating from Mexico, the plant has been introduced to Indonesia, where it often grows unnoticed in home gardens, leading to its frequent removal. It is estimated to have been introduced into Indonesia in 1998. The taxonomy of Japanese papaya is as follows:

- Kingdom: Plantae
- Division: Magnoliophyta
- Class: Magnoliopsida
- Order: Malpighiales
- Family: Euphorbiaceae
- Genus: *Cnidoscolus*
- Species: *Cnidoscolus aconitifolius* (Mill.) I.M. Johnst

Japanese papaya thrives in a wide range of soils and climates, including hot, rainy, and arid regions. It grows rapidly at high temperatures, and new leaves regenerate quickly after harvest. In Indonesia, plants typically reach heights of around three meters with more than 30 productive stems and branches. Propagation is mainly through stem cuttings, which are easily distributed. The leaves are palatable, non-bitter, and preferred over regular papaya leaves, with lower moisture content than most other leafy greens.

In Mexico, Japanese papaya is widely used as a food source, medicinal plant, and ornamental shrub. It has been reported to lower cholesterol levels, exhibit antidiabetic and antioxidant properties, and provide hepatoprotective benefits (Maidah & Hariani, 2022; Kuri-García et al., 2017). Its nutritional profile includes protein, calcium, iron, phosphorus, vitamin A, niacin, riboflavin, and vitamin C, with carposide acting as a natural anthelmintic. Roots and latex also contain papayotin, carpaine, caoutchouc, carposide, and vitamins (Nulhakim et al., 2020).

Japanese papaya is also a promising forage crop for livestock, especially ruminants, due to its adaptability and nutritional value. Reported composition includes 82.99-86.40%

moisture, 13.60-17.01% dry matter, 1.665-2.67% ash (John and Opoyemi, 2015; Sudartini et al., 2019). The crude protein content of chaya leaves varies considerably. According to the study conducted by Setiasih et al. (2024), the crude protein content of chaya leaves is 29.39%, while the crude fiber and fat contents are 13.63% and 6.93%, respectively. A review by Panghal et al. (2021) further noted that its leaves contain 41.895% carbohydrates, and provide 14.6 MJ/kg of energy. The protein content is rich in amino acids, comprising 44.80% essential and 55.19% non-essential amino acids.

Despite these advantages, the leaves contain antinutritional compounds such as phytic acid and oxalates, which may limit their effectiveness as livestock feed (Babalola & Alabi, 2015). However, processing methods such as wilting, sun-drying, and boiling can reduce these compounds (Ramteke et al., 2019). Boiling, in particular, has been shown to significantly decrease oxalate, phytate, and tannin levels (Babalola & Alabi, 2015).

Research on ruminant feeding has demonstrated that incorporating Japanese papaya leaf pellets improves rumen fermentation and reduces methane emissions (Totakul et al., 2021; Totakul et al., 2022). Pelletizing also enhances feed handling and reduces antinutritional factors. Totakul et al. (2021) recommended including 6% leaf pellets to increase ruminal volatile fatty acids (VFA) and ammonia (NH_3) levels while lowering rumen protozoa density, which is correlated with methane reduction. Changes in rumen fermentation intermediates may further improve production traits, such as milk and meat yield. Accordingly, Japanese papaya leaves are regarded as effective rumen modifiers/enhancers (Ampapon et al., 2022) and are recommended for mitigating methane emissions (Angeles-Mayorga et al., 2022).

RESEARCH METHODS

Research Period and Location

The field research on the forage production characteristics of Japanese papaya was conducted from July to August 2024 at two locations: Dinoyo Permai Timur Street, Dinoyo Village, and the Faculty of Animal Science, Universitas Brawijaya, Malang, located on Veteran Street, Ketawanggede Village, Lowokwaru District, Malang City. The forage nutrient composition analysis was carried out at the Testing Laboratory of the Livestock Training Center (BBPP) in Batu City.

Research Materials

The materials used in this study consisted of four mature Japanese papaya plants ready for harvest, which grew naturally or were cultivated as living fences and boundary plants. The equipment used included a vernier caliper (measurement range 0.1–15 cm), a measuring tape (range 1–5000 cm), a manual tally counter (range 1–9999), and a digital scale (range 1–5000 g).

Research Method

This study used a case study method with direct field observations and measurements of four Japanese papaya plants growing in Malang City. Measurements were conducted to determine the diameter of the main branch, number of sub-branches, length of sub-branches, forage yield, and nutrient content of Japanese papaya. The nutrient composition of Japanese papaya forage is presented in Table 1.

Table 1. Nutrient composition of Japanese papaya forage

Forage part	Nutrient content				
	DM (%)	OM	CP (% DM)	CF	EE
Leaves	16.71	91.05	23.96	13.57	5.34
Stems	14.06	87.57	7.76	32.79	1.96
Leaves and stems	15.23	89.97	11.44	31.31	4.94

Research Procedure

The research procedure involved several stages. The initial stage included selecting mature Japanese papaya plants that grew naturally or were used as living fences and boundary plants in Malang City. Equipment was prepared for measuring forage production characteristics. Data collection was carried out by measuring the main branch diameter, number of sub-branches, length of sub-branches, forage yield, and nutrient content.

Research Variables

The variables observed in this study included:

1. Correlation and regression between main branch diameter and the number of sub-branches of Japanese papaya.
2. Correlation and regression between main branch diameter and the length of sub-branches of Japanese papaya.

3. Correlation and regression between main branch diameter and forage yield of Japanese papaya.
4. Correlation and regression between main branch diameter and nutrient content of Japanese papaya forage.

Data Analysis

The collected data were analyzed using correlation and simple linear regression to evaluate the relationships between the main branch diameter and forage production characteristics, including the number and length of sub-branches, forage yield, and nutrient content of Japanese papaya. All statistical analyses were performed using Microsoft Excel 2019, with a significance level set at $p < 0.05$ to determine statistically significant relationships.

RESULTS AND DISCUSSION

1. Relationship Between Main Branch Diameter and Forage Production Characteristics

a. Number of Sub-branches

The correlation analysis showed that main branch diameter had a very strong and significant relationship with the number of sub-branches ($r = 0.94$; $P < 0.01$). Larger main branch diameters supported the formation of more sub-branches, which indicates better vegetative growth potential (Figure 1). This relationship occurs because thicker branches contain more vascular tissues, enhancing the transport of water and nutrients to developing buds (Rustani & Susanto, 2019). As a result, plants with larger diameters can allocate more resources for branch and leaf formation, leading to greater forage availability.

b. Forage Yield

A strong positive correlation ($r = 0.98$; $P < 0.01$) was found between main branch diameter and total forage yield. Plants with larger diameters produced more fresh biomass and dry matter, confirming that branch thickness is a reliable predictor of productivity. Physiologically, thicker branches often indicate higher carbohydrate reserves and photosynthetic capacity, which enhance leaf and stem biomass production (Khairy et al., 2022). This result supports the idea that morphological indicators can be used as simple field-based estimators of forage yield potential.

c. Nutrient Composition

Main branch diameter was also positively correlated with nutrient content—particularly crude protein (CP), crude fiber (CF), and ether extract (EE)—with correlation coefficients above 0.95 ($P < 0.01$). This suggests that plants with larger diameters not only yield more biomass but also possess higher nutritional quality. Increased nutrient content may result from greater leaf density and enhanced nitrogen metabolism due to improved nutrient translocation. Santoso and Jayaputra (2020) noted that branch development is closely associated with leaf production, which contributes directly to protein accumulation in foliage.

2. Prediction of Forage Production Using Regression Models

Regression analysis produced predictive equations linking main branch diameter to forage characteristics (Table 1). The strongest predictive model was found for the number of sub-branches (R^2 = 88.24%), followed by forage yield and nutrient components (R^2 = 95.53%). The smallest deviation (0.45%) indicated that branch diameter could be used as an accurate estimator for sub-branch number. However, sub-branch length showed higher variation (deviation = 5.47%), likely due to environmental influences such as light intensity, humidity, and soil fertility (Nurjaya et al., 2023).

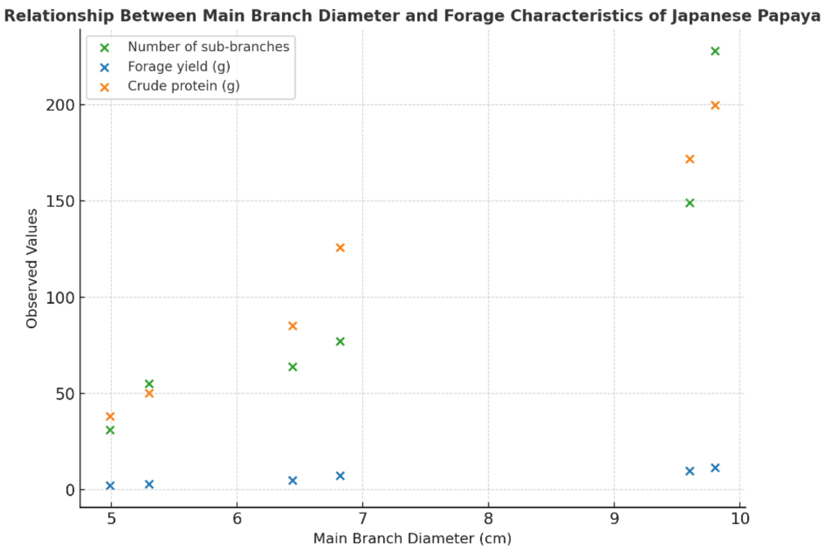

Figure 1. Correlation between main branch diameter and forage characteristics of Japanese papaya (*Cnidoscolus aconitifolius*): number of sub-branches, forage yield, and crude protein content.

From an application standpoint, these findings demonstrate that simple morphological measurements—particularly main branch diameter—can be used by farmers to estimate forage production and quality without complex laboratory analysis. This method is especially useful for on-farm selection of Japanese papaya plants as green concentrate sources for ruminants. Compared to other forages such as *Indigofera* or *Leucaena*, Japanese papaya offers comparable protein levels with easier cultivation and better adaptability to marginal soils (Gustiar et al., 2023).

Table 1. Regression equations and deviations for predicting forage production characteristics of Japanese papaya (Cnidoscolus aconitifolius)

Relationship	Regression Equation	Deviation (%)
Main branch diameter vs. number of sub-branches	Y = -138.10 + 33.35X	0.45
Main branch diameter vs. sub-branch length	Y = -7184.52 + 1724.87X	5.47
Main branch diameter vs. forage yield	Y = -6205.31 + 1763.17X	3.15
Main branch diameter vs. DM production	Y = -945.01 + 268.51X	3.15
Main branch diameter vs. OM production	Y = -850.23 + 241.58X	3.15
Main branch diameter vs. CP production	Y = -108.11 + 30.72X	3.15
Main branch diameter vs. CF production	Y = -295.88 + 84.07X	3.15
Main branch diameter vs. EE production	Y = -46.68 + 13.26X	3.15

CONCLUSION

This study demonstrated that the main branch diameter of *Cnidoscolus aconitifolius* (Japanese papaya) is strongly correlated with key forage production traits—including the number of sub-branches, forage yield, and nutrient composition. These results indicate that branch diameter can serve as a simple, reliable field indicator for predicting both the quantity and quality of forage.

The findings highlight the potential of Japanese papaya as a sustainable and locally available feed resource for ruminants, reducing dependence on expensive commercial concentrates. This morphological approach can support farmers in selecting high-yield plants and improving feed management efficiency. Future studies should validate these relationships under different environmental and management conditions to optimize cultivation practices and further strengthen the role of Japanese papaya in sustainable livestock feed systems.

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