

The Different Plant Fractions of Nutrients and Anti-Nutrients Compositions of *Cajanus Cajan* Forage from Malaysia and Indonesia

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Cajanus cajan is predominantly farmed as a grain crop, and its seeds are utilized for human food. The foliage can be gathered and fed to livestock, both fresh and preserved. *C. cajan* fodder is an important forage due to its high output potential and excellent feed quality. Although Malaysia and Indonesia are both in Southeast Asia with tropical temperatures, environmental differences such as soil fertility, humidity, and rainfall can all have an impact on *C. cajan* plant growth. This study aimed to determine and compare the plant height, yield, and nutritional and anti-nutritional compositions of different plant fractions of *C. cajan* forage from Malaysia and Indonesia. *C. cajan* was planted in two distinct locations in Malaysia and Indonesia, with samples taken from randomly selected plants. Harvesting was conducted 12 weeks after planting. An independent t-test was performed on the data for plant height and total dry matter (DM) production. Proximate analyses of the anti-nutritional and Ca and P contents of different parts of *C. cajan* forage were carried out through ANOVA. Results indicate that plants cultivated in Malaysia are higher ($P < 0.05$), with higher stem and leaf values, resulting in a greater overall yield compared to plants in Indonesia. Additionally, *C. cajan* grown in Malaysia exhibited higher nutritional contents of neutral detergent fiber, acid detergent fiber, and acid detergent lignin than those grown in Indonesia ($P < 0.05$). The anti-nutritional values of *C. cajan* grown in Malaysia were higher in phenol, condensed tannin, and flavonoids. In conclusion, the study shows that *C. cajan* grown in Malaysia has superior growth, yield, and certain nutritional and anti-nutritional contents compared to that grown in Indonesia. These findings suggest the potential for optimizing *C. cajan* cultivation practices in Malaysia to maximize forage yield and quality.

Keywords: Yield, Nutritional composition, Anti-nutritional content, *Cajanus cajan* forage.

INTRODUCTION

Cajanus cajan (L.) Millsp. from the *Fabaceae* family (alt. *Leguminosae*) has many common names, but its most popular names are Congo pea, pigeon pea, and yellow dahl. The plant is an annual or short-lived perennial shrub or small tree with trifoliate, alternate leaves set in a spiral around the stem. The flowers are typically yellow, and the fruit is a flat pod (5–9 cm long, 12–13 mm wide, containing 2–9 oval to round seeds varying in color from light beige to dark brown); the plant can grow up to 1–4 m and usually has an erect woody base (Food and Agriculture Organization, 2016). *C. cajan* is primarily grown as a grain crop, its seeds being used for human consumption, with over 4 million ha cultivated worldwide (Foster *et al.*, 2009). The foliage can be harvested and fed to livestock, either fresh or preserved (Butler & Trumble, 2012). *C. cajan* cultivars have been developed and

tested for grain and forage production (Foster *et al.*, 2009). *C. cajan* fodder remains as an essential forage due to its high output potential and outstanding feed quality (Tolera *et al.*, 2012). *C. cajan* has a wide range of applications in animal feeding. It provides highly profitable, delicious, and protein-rich pods, and its leaves are superior. In situations when alfalfa cannot be grown, *C. cajan* leaves can occasionally be used in place of alfalfa in ruminant diet. Occasionally, its seeds and other parts are used to prepare animal feed (Phatak *et al.*, 1993). In tropical regions, *C. cajan* is produced all year round. The production of *C. cajan* forage is higher in areas with warm temperatures than in areas with cold temperatures (Rao *et al.*, 2002). Furthermore, a variety of interrelated factors, including the environment, management techniques, and genetics, influence the forage yield and quality of *C. cajan* (Daniel and Ong, 1990). Environmental elements, such as temperature, precipitation, and location, effects on the

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Table 1. Geographical location, climate and weather conditions of the research location.

Location	Konda District, Southeast Sulawesi, Indonesia	Field 15, University of Putra Malaysia (UPM), Serdang, Selangor, Malaysia
Latitude	121.58° east	3°00'24.3 north
Longitude	123.16° east	101°42.'10.3 east
Climate zone	tropical humid zone	tropical humid zone
Average minimum temperature	26 °C	26 °C
Average maximum temperature	32 °C	34 °C
Average relative humidity	77%	74%
Average Annual rainfall	3179 mm	2507 mm

quantity and quality of forage (Kim and Sung, 2023). Although Malaysia and Indonesia are both in Southeast Asia and have tropical climates, they exhibit environmental variations, such as soil fertility, humidity, and rainfall, which can affect the growth of *C.cajan* plants. The objective of this experiment is to evaluate the plant height, yield production, and nutritional and anti-nutritional factors of *C.cajan* forage from Malaysia and Indonesia.

MATERIALS AND METHODS

Experimental Site: The details of the soil are provided in the Planting and Field Management section. The soil texture of the experimental area was classified in accordance with the soil taxonomy classification of the United States Department of Agriculture (USDA) and determined via textural autolookup, shown below.

Table 2. Soil characteristics at Field 15 UPM, Serdang, Malaysia and Konda District, Southeast Sulawesi, Indonesia.

Soil property	Malaysia	Indonesia
Soil type	Clay	Clay
Sand (%)	30.53	33.27
Silt (%)	42.14	39.10
Clay (%)	45.13	40.25
N (ppm)	42.50	39.10
P (ppm)	37.60	43.70
K (ppm)	26.80	30.50
pH	5.50	5.50

The area was ploughed using a tractor. The seeds of *C.cajan* were sown with three seeds in each hole. The spacing between each plant was 40 cm × 50 cm. Herbicide was sprayed to reduce the growth of weeds 2 weeks after planting.

Data Collection and Harvesting: Plant height was determined from randomly selected plants. It was measured from the ground to the tip of the plant by using a measuring tape. The height of five randomly selected plants was measured before harvesting, and the average value was regarded as plant height. Similarly, the numbers of leaves and stems of the five plants were determined, and the average

value was taken. Harvesting was performed 12 weeks after planting. A sharp knife was used to harvest foliage. The plants were cut approximately 30 cm from the ground level. After harvesting, the whole plant was weighed to calculate the total fresh biomass yield and total leaf yield. Furthermore, *C.cajan* forage was placed in a forced-air oven at 60°C until a constant weight was achieved.

Calculation of Dry Matter (DM) Yield: A sample was taken from a quadrat with an area of 2 m², followed by weighing, drying, and reweighing. The DM yield in kilogram per hectare was determined by calculating as follows:

$$\text{DM yield (kg/ha)} = \text{Dry weight (kg)} \times 10000 \text{ m}^2/2 \text{ m}^2.$$

Chemical Analysis of *C.cajan* Forage: The *C.cajan* forage samples were analyzed using the standard procedures for chemical composition for DM, organic matter (OM), crude protein (CP) (AOAC International, 2012) neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) (van Soest *et al.*, 1991). The Ca and P contents of the samples were determined using the wet digestion method (AOAC International, 2012).

Determination of Anti-nutrient Content: Total phenols, tannins, and non-tannin phenols were estimated following the procedure of Makkar *et al.* (1993). The estimation of condensed tannins was quantified following the method of Porter *et al.* (1985). For flavonoid estimation, the method of Atanassova *et al.* (2011) was used. The determination of total saponins was in accordance with the method of Sanbongi *et al.* (1998) with some modifications. Saponin content was determined in accordance with Makkar *et al.* (2007).

Statistical Analysis: The independent *t*-test was performed on the data regarding plant height and total DM production. The proximate analyses of the anti-nutritional, Ca, and P contents of different parts of *C.cajan* forage were conducted using ANOVA in SPSS version 20 software (2011).

RESULTS

Yield: Growth and DM yield production under different treatments are presented in Table 3. Plant height, total foliage yield, leaf yield, and leaf stem ratio were significantly affected by the location of planting, with higher growth and



DM yield in Malaysia than in Indonesia. By contrast, stem yield was not affected ($P>0.05$) by the location of planting.

Table 3. Plant height and total yield production of *C.cajan* forage in Malaysia and Indonesia.

Variables	Location		SEM	Sig.
	Malaysia	Indonesia		
Plant height (cm)	154.80	151.40	0.650	S
Dry matter yield (t h ⁻¹)				
Total foliage (t h ⁻¹)	3.471	3.269	0.035	S
Leaf (t h ⁻¹)	1.935	1.737	0.034	S
Stem (t h ⁻¹)	1.535	1.531	0.010	NS
Leaf:Stem	1.2	1.1	0.034	S

SEM= standard error of the mean; NS= not significant; S= significant $P<0.05$; t h⁻¹: tonne per hectare.

Nutritional Composition: The nutritional composition under various treatments is presented in Table 4. The chemical composition of *C. cajan* is unaffected ($P>0.05$) by plant fraction or planting location. Otherwise, differences in plant fraction affect all the chemical compositions of the *C.cajan* tree. However, differences in location affect ($P<0.05$) the NDF, ADF, and ADL values of *C.cajan* (Figures 1, 2, and 3), but not DM, OM, CP, EE, Ca, and P.

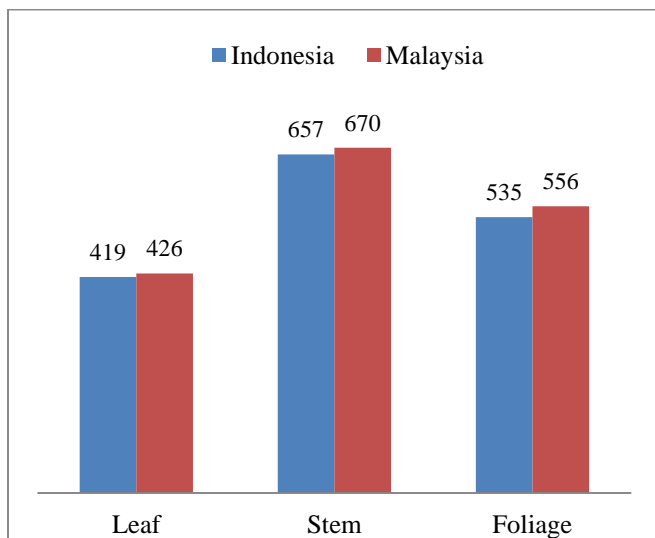


Figure 1. NDF content of *C.cajan* forage in Malaysia and Indonesia.

DM and OM values were significantly different ($P<0.05$) from the *C.cajan* plant fraction. The stem had the highest DM value, while the leaf had the lowest. By contrast, the leaf had the highest OM content, while the stem had the lowest. *C.cajan* grown in Malaysia and Indonesia exhibited no significant differences ($P<0.05$) in DM and OM values.

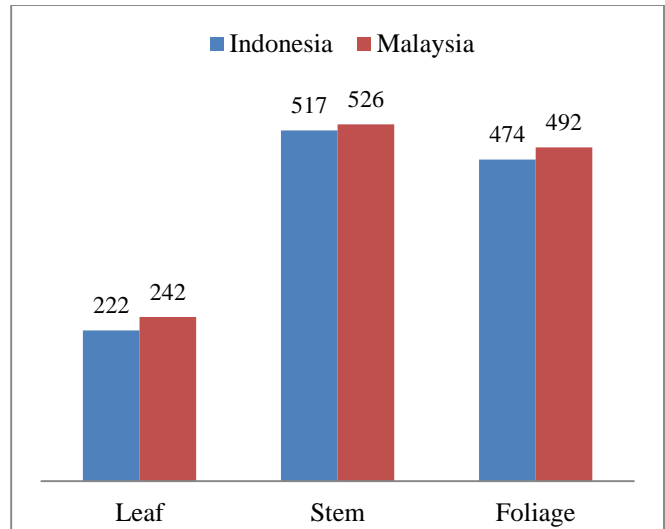


Figure 2. ADF content of *C.cajan* forage in Malaysia and Indonesia.

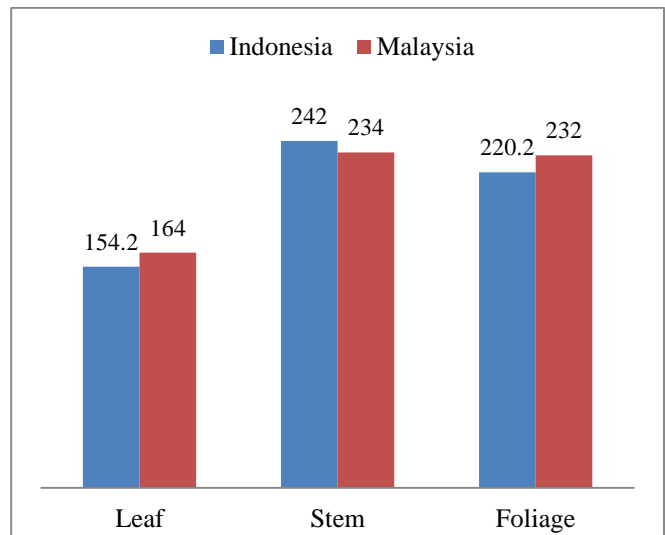


Figure 3. ADL content of *C.cajan* forage in Malaysia and Indonesia.

Location and plant fraction treatments exerted a significant effect ($P<0.05$) on the NDF, ADF, and ADL contents of *C.cajan* forage (Figure 1, 2, 3). The highest NDF, ADF, and ADL values were found in the stem, while the lowest values were found in the leaf. Furthermore, *C.cajan* grown in Malaysia had higher NDF, ADF, and ADL contents than *C.cajan* grown in Indonesia. The NDF content of *C.cajan* forage planted in Malaysia was 426–670g kg⁻¹ DM, the ADF value was 242–526g kg⁻¹ DM, and the ADL content was 164–234 g kg⁻¹ DM. Meanwhile, *C.cajan* planted in Indonesia had an NDF content of 419–657g kg⁻¹ DM, ADF content of 222–517 g kg⁻¹ DM, and ADL value of 154–242 g kg⁻¹ DM.



Table 4. Chemical composition, C and P contents of different plant fractions of *C.cajan* forage in Malaysia and Indonesia (g kg⁻¹ DM).

Item	Location		Mean	SEM
	Malaysia	Indonesia		
DM				
Leaf	354.00	360.00	357.00 ^c	0.23
Stem	376.00	378.00	377.00 ^a	0.23
Total Foliage	367.00	367.00	367.00 ^b	0.21
OM				
Leaf	926.00	930.00	928.00 ^a	0.23
Stem	906.00	917.00	911.50 ^c	0.17
Total Foliage	924.00	921.00	922.50 ^b	0.23
CP				
Leaf	206.00	201.00	203.50 ^a	0.21
Stem	136.00	135.00	135.50 ^c	0.14
Total Foliage	178.00	174.80	176.40 ^b	0.22
EE				
Leaf	29.80	30.40	30.10 ^a	0.04
Stem	12.40	13.20	12.80 ^c	0.03
Total Foliage	14.00	14.60	14.30 ^b	0.04
Ca				
Leaf	6,8	6,8	6,8 ^c	0.05
Stem	9,8	9,8	9,8 ^a	0.03
Total Foliage	8,6	8,7	8,65 ^b	0.04
P				
Leaf	2.04	2.12	2.08 ^c	0.02
Stem	2.24	2.20	2.22 ^a	0.02
Total Foliage	2.16	2.18	2.17 ^b	0.03

^{a,b,c} In the same column and in each treatment, different superscripts indicate a significant difference among treatment at $P<0.05$ level. SEM= standard error of the mean.

No significant ($P>0.05$) differences were found in the PP, EE, Ca, and P contents between *C.cajan* forage planted in Malaysia and Indonesia (Table 4). By contrast, plant fraction treatment exerted a significant effect ($P<0.05$) on the P, EE, Ca, and P contents of *C.cajan* plants. The highest CP and EE values were found in the leaves, while the lowest values were found in the stem.

Table 5. Total phenols, tannins, non-tannin phenols, condensed tannins, total flavonoids, and total saponins in *C. cajan* forage in Malaysia and Indonesia (mg g⁻¹ DW).

Variables	Location		SEM	Sig.
	Malaysia	Indonesia		
Total phenols	102.98	101.00	0.149	S
Non-tannins	42.10	41.5	0.171	NS
Total tannins	60.1	60.5	0.130	NS
Condensed tannins	6.4	5.9	0.110	S
Flavonoids	51.38	50.70	0.194	NS
Saponins	60.9	58.24	0.331	S

DW= dry weight; SEM= standard error of the mean; NS= not significant; S = significant; $P<0.05$.

The total phenol, condensed tannin, and saponin contents were significantly different ($P<0.05$) between *C. cajan* forage grown in Malaysia and Indonesia (Table5). By contrast, no significant ($P>0.05$) differences were found in the non-tannin acid, total tannin, and flavonoid contents between *C. cajan* forage grown in Malaysia and Indonesia.

DISCUSSION

Growth and DM Yield: The results of the present study showed that plant height at harvest varied between the locations, and plants grown in Malaysia were taller 3.8 cm than those grown in Indonesia (Table 3). The findings from this study suggest that *C. cajan* cultivated in Malaysia has a higher yield and better growth characteristics compared to those grown in Indonesia. Specifically, plants in Malaysia exhibit taller plant height and higher dry matter (DM) yield, particularly in the foliage and leaves. This indicates a potential for higher forage production in Malaysia, which could be beneficial for increasing the overall biomass available for agricultural use. The superior yield and growth can be attributed to the slightly more favorable growing conditions in Malaysia, such as slightly higher maximum temperatures and different rainfall patterns. This finding was supported by [Mekonen et al. \(2022\)](#), who reported that location affected the height of *C.cajan* tree. Variability among locations maybe attributed to the rainfall and temperature in the locations ([Mishra et al., 2016](#)) and the physicochemical characteristics of the soil ([Behera et al., 2020](#)). The plant height obtained in the current study was higher than the result reported by [Jabessa and Bekele \(2021\)](#), i.e.,104.90 cm, but lower than that found by [Ansari and Mahmood \(2017\)](#), i.e., 188 cm.

The yield of *C. cajan* obtained in the present study was also comparable with the biomass production of alfalfa ([Geleti et al., 2014](#)) but higher than those of *Morus alba* ([Saddul et al., 2004](#)), *Sesbania grandiflora* ([Catchpoole and Blair, 1990](#)), *Gliricidia sepium*, *Leucaena leucocephala* ([Ella et al., 1989](#)), *Sesbania sesban* ([Galang et al., 1990](#)), and *Lablab* ([Ratnawaty and Chuzaemi, 2013](#)). These findings suggest that *C. cajan* has the potential to produce higher biomass than *Gliricidia*, *Leucaena*, *Sesbania*, *Macroptilium*, *Lablab*, or *Morus alba*.

Nutrient Composition: The study shows that the nutritional content of *C.cajan* grown in Malaysia is superior in certain aspects compared to that grown in Indonesia ($P<0.05$). The higher levels of neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) found in Malaysian plants suggest better forage quality for ruminants, as these fibers are essential for proper digestion and nutrient absorption. Additionally, crude protein (CP) and ether extract (EE) contents are similar in both locations, The DM content of different fractions of *C. cajan* was similar to that reported by [Tenakwa et al.\(2022\)](#) where the NDF, ADF, and ADL



contents of *C. cajan* tree were significantly different ($P < 0.05$) in terms of plant fractions and locations. Leaf fraction had the lowest content of NDF, ADF, and ADL, whereas stem fraction had the highest NDF, ADF, and ADL contents. The high NDF, ADF, and ADL contents of stem fraction is related to the anatomical structure of *C. cajan* plant, where in fibers are mostly in the stem for support (Van Soest *et al.*, 1991). Furthermore, significant differences ($P < 0.05$) were noted in the contents of NDF, ADF, and ADL between *C. cajan* plants grown in Malaysia and Indonesia. The contents of NDF, ADF, and ADL in whole plant parts are higher in Malaysia than in Indonesia. This result can be caused by differences in humidity, temperature, and soil conditions (Radkowski *et al.*, 2020). The NDF, ADF, and ADL values of *C. cajan* grown in Malaysia and Indonesia are still the same as those of other forages that are frequently used for animal feed, such as *Gliricidia sepium*, *L.leucocephala*, and *Sesbania macrantha* (Dzowela *et al.*, 1995). Future research could be conducted to investigate the digestibility and rumen degradability of *C. cajan* forage from both locations.

No significant ($P > 0.05$) differences were found in the CP content of the total foliage and leaf or stem fractions of *C.cajan* grown in Malaysia and Indonesia (Table 3). The overall CP concentration in the leaves ($203.50 \text{ g kg}^{-1} \text{ DM}$) was greater than those in the whole plant ($176.40 \text{ g kg}^{-1} \text{ DM}$) and stem fraction ($135.50 \text{ g kg}^{-1} \text{ DM}$) (Table 3). The CP concentration of *C.cajan* leaves is comparable with those of alfalfa (Chen *et al.*, 2019), *L.leucocephala* (Ella *et al.*, 1989), and *Moringa* (Yaméogo *et al.*, 2011). Therefore, the CP concentration of *C.cajan* stem is higher than those of mature forages, such as Guinea grass (*Panicum maximum*) in early or full bloom ($55.0 \text{ g kg}^{-1} \text{ DM}$ and $66.0 \text{ g kg}^{-1} \text{ DM}$, respectively) or Napier grass (*Pennisetum purpureum*) post-ripe ($41.0 \text{ g kg}^{-1} \text{ DM}$), (National Research Council [NRC], 1981). The CP content of stem ($135.50 \text{ g kg}^{-1} \text{ DM}$) was higher than the critical level of CP (6.5%–8.5% DM) in forages to support the activity of the rumen microorganisms (Shayo, 1997). The mean CP content of *C.cajan* whole plant ($173.33 \text{ g kg}^{-1} \text{ DM}$) is comparable with that of alfalfa ($140\text{--}200 \text{ g kg}^{-1} \text{ DM}$) or concentrate (NRC, 1981). This result places *C.cajan* plant in the same rank as high-quality forages.

The Ca and P contents in stem were higher than in leaves for both locations ($P < 0.05$). The ranges of Ca content ($6.8\text{--}9.8 \text{ g kg}^{-1} \text{ DM}$) and P content ($2.04\text{--}2.24 \text{ g kg}^{-1} \text{ DM}$) in stem to leaves in Malaysia and Indonesia in the present study were comparable with those reported by Henderson *et al.* (1995) but lower than those found by Chen *et al.* (2019). Differences in Ca and P values in *C.cajan* plants can be caused by differences in species, soil moisture, and nutrient availability (Atakoun *et al.*, 2023). McDowell (2003) reported that 2.7 g kg^{-1} and 2.8 g kg^{-1} of P and 4.6 , 5.1 , and 30.0 g kg^{-1} of Ca would be sufficient for cattle, sheep, and goats. The Ca level of the total foliage ranged from $6.8 \text{ g kg}^{-1} \text{ DM}$ to $9.8 \text{ g kg}^{-1} \text{ DM}$, which may support the requirement of ruminant animals.

Anti-nutrient Composition: Significant differences ($P < 0.05$) were observed in the phenol, condensed tannin, and saponin values of *C.cajan* forage grown in Malaysia and Indonesia (Table 4). By contrast, no difference was noted in total tannin, non-tannin, and flavonoid values between plants grown in Malaysia and Indonesia. This difference in values can be attributed to differences in soil types and environmental conditions (Barry and Forss, 1983). The total tannin values of *C.cajan* ($6.1\text{--}6.5 \text{ g kg}^{-1} \text{ DM}$ basis) are comparable with those found in the literature. Godoy and Batista (1997) reported $2\text{--}40 \text{ mg g}^{-1}$ tannins (DM basis) for *C.cajan*, while Getachew (1999) reported 12 mg kg^{-1} . The total tannin content is still safe for goat consumption. Muir (2011) asserted that the intake of tannins at low to moderate levels ($2\text{--}4 \text{ mg g}^{-1} \text{ DM}$) in animal feed exerts a beneficial effect on the protein metabolism of ruminants, reduces bloating, and has an anthelmintic effect on gastrointestinal parasites. *C.cajan* has lower anti-nutritional phenol to condensed tannin content than *L.leucocephala* and *Sesbania* (Vitti *et al.*, 2005).

Tannin was traditionally considered an anti-nutrition compound for animals, but it is now recognized to have nutritional benefits, particularly in protecting high-quality dietary proteins from microbe degradation in rumen. The presence of tannin in *C. cajan* has been considered to chemically support its function as protein supply forages. Tannin may improve the use of proteins contained in *C. cajan* herbage. Tannin exhibits positive effects in reducing thenon-protein N of round bale silages (Schiaivone *et al.*, 2008; Tabacco *et al.*, 2006) and improving the fermentability of soya meal N in the rumen (Rios-Gonzalez *et al.*, 2002). The anti-nutrient contents of plants are affected by plant species, genotype, and stage of growth. They may vary with plant part (leaf, stem, inflorescence, and seed), season of growth, and other specific environmental factors, such as temperature, rainfall, cutting, and defoliation by grazing herbivores, including insects. A major characteristic is their propensity to form chemical complexes not only with proteins but also with other compounds, such as polysaccharides, nucleic acids, steroids, alkaloids, and saponins (Lorusso *et al.*, 1996; Mueller-Harvey, 2006).

Conclusion: The study indicates that *C. cajan* cultivated in Malaysia exhibits superior yield and growth characteristics compared to Indonesia, with higher plants and higher dry matter yield, particularly in foliage and leaves. This suggests greater forage production potential in Malaysia, beneficial for increasing agricultural biomass. The superior growth is attributed to more favorable growing conditions, such as slightly higher temperatures and different rainfall patterns. Nutritionally, Malaysian *C. cajan* has higher levels of essential fibers (NDF, ADF, ADL), enhancing forage quality for ruminants. Despite the elevated antinutrient content, which includes phenols, condensed tannins, and flavonoids, it remains within normal ranges. These findings impact



agriculture by potentially increasing biomass production, benefit livestock with better forage quality.

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