Open Access

J. Glob. Innov. Agric. Sci., 2025, 13(3):1030-1037
ISSN (Online): 2788-4546; ISSN (Print):2788-4538
DOI: https://doi.org/10.22194/JGIAS/25.1406
http://www.jgiass.com

Society for Innovative Agiculture

Nutrient and Anti-Nutrient Compositions in different Plant Fractions of *Cajanus cajan* Forage from Malaysia and Indonesia

Dian Agustina Abidinsyah[1,2,*], Halimatun Yaakub[1], Iswan B. Suyub[1] and Shokri Jusoh[1]

[1]Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, Serdang, Selangor, Malaysia;
[2]Department of Animal Science, Faculty of Animal Science, Halu Oleo University, Kendari, Sulawesi Tenggara, Indonesia
[*]Corresponding author's e-mail: dian.agustina@uho.ac.id

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: Forage production, silage, dry matter yield, nutritional composition, anti-nutritional content .

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 and 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

Abidinsyah, D.A., H. Yaakub, I.B. Suyub and S. Jusoh. 2025. Nutrient and Anti-Nutrient Compositions in different Plant Fractions of *Cajanus cajan* Forage from Malaysia and Indonesia. Journal of Global Innovations in Agricultural Sciences 13:1030-1037.
[Received 7 Jun 2024; Accepted 8 Jul 2024; Published 21 Jun 2025]

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	3º00'24.3 north
Longitude	123.16' east	101º42.'10.3 east
Climate zone	tropical humid zone	tropical humid zone
Average minimum temperature	26 ºC	26 ºC
Average maximum temperature	32 ºC	34 ºC
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 m^2, followed by weighing, drying, and reweighing. The DM yield in kilogram per hectare was determined by calculating as follows:

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

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 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 Malaysia	Location Indonesia	SEM	Sig.
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.

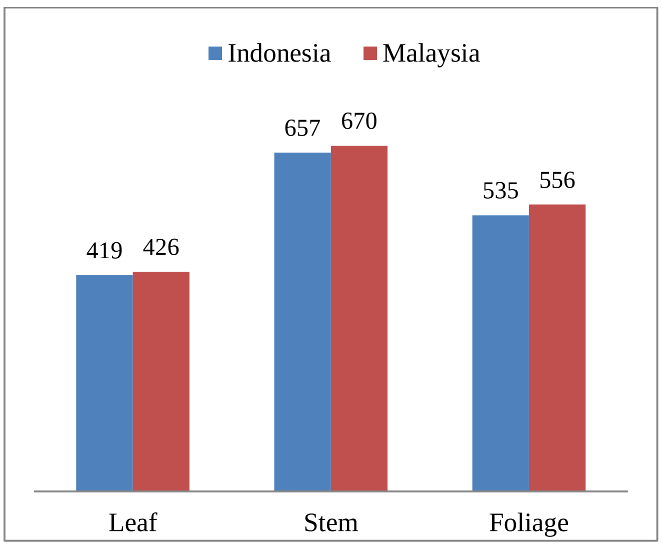

Figure 1. NDF content of *C. cajan* forage in Malaysia and Indonesia.

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.

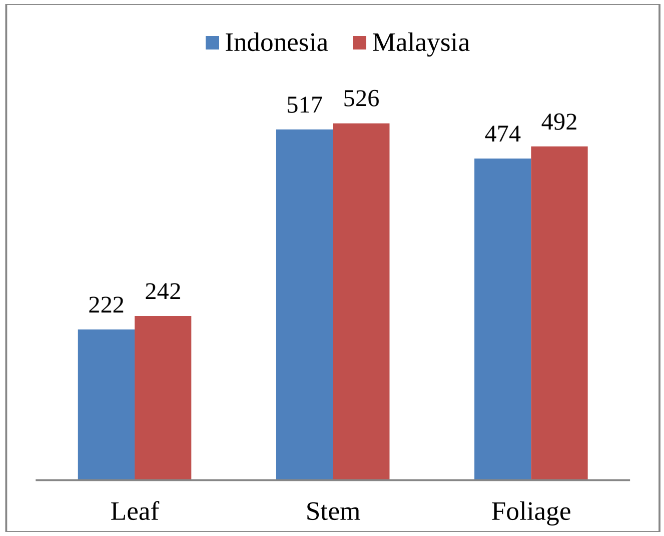

Figure 2. ADF content of *C. cajan* forage in Malaysia and Indonesia.

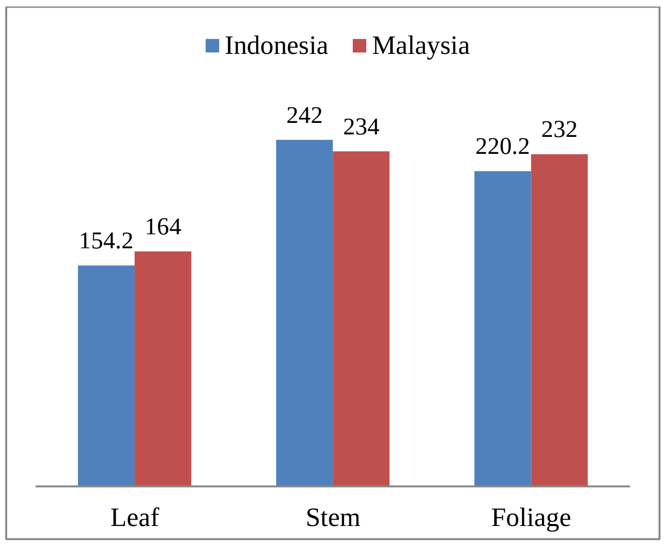

Figure 3. ADL content of *C. cajan* forage in Malaysia and Indonesia.

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 was164–234 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 Pcontents 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 g kg^{-1} DM) was greater than those in the whole plant (176.40 g kg^{-1} DM) and stem fraction (135.50 g kg^{-1} 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 g kg^{-1} DM and 66.0 g kg^{-1} DM, respectively) or Napier grass (*Pennisetum purpureum*) post-ripe (41.0 g kg^{-1} DM), (National Research Council [NRC], 1981). The CP content of stem (135.50 g kg^{-1} 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 g kg^{-1} DM) is comparable with that of alfalfa (140–200 g kg^{-1} 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 (6.8–9.8 g kg^{-1} DM) and P content (2.04–2.24 g kg^{-1} 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 2.7g 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 6.8g kg^{-1} DM to 9.8 g kg^{-1} 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* (6.1–6.5 g kg^{-1} DM basis) are comparable with those found in the literature. Godoy and Batista (1997) reported 2–40 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 (2–4 mg g^{-1} 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. leucochepala* 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 (Schiavone *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 parts (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 anti-input content, which includes phenols, condensed tannins, and flavonoids, it remains within normal ranges. These findings impact agriculture by potentially increasing biomass production, benefiting livestock with better forage quality.

CRediT author statement**:** D.A. Abidinsyah was responsible for the overall research, the writing of the research report, and the writing of the article. H. Yaakub prepared the draft. I.B. Suyub and S. Jusoh reviewed and finalized the draft article.

Conflict of interest**:** The authors declare no conflict of interest.

Acknowledgment**:** The authors would like to thank the Southeast Asian Regional Center for Graduate Study and Research in Agriculture for providing financial support.

Funding**:** This research was funded by the Southeast Asian Regional Center for Graduate Study and Research in Agriculture.

Ethical statement**:** N/A

Availability of data and materials**:** All data is published in this manuscript.

Consent for publication**:** All authors submitted consent to publish this research. article in JGIAS.

SDG's addressed**:** SDG 2: Zero Hunger, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action ; SDG 15: Life on Land.

Policy referred**:** Agricultural and Livestock Feed Policy, Land Use and Crop Optimization Policy, Sustainable Agriculture and Climate Adaptation Policy.

Publisher's note**:** All claims stated in this article are exclusively those of the authors and do not necessarily represent those of their affiliated organizations or those of the publisher, the editors, and the reviewers. Any product that may be evaluated/assessed in this article or claimed by its manufacturer is not guaranteed or endorsed by the publisher/editors.

REFERENCES

Ansari, R. A. and I. Mahmood. 2017. Optimization of organic and bio-organic fertilizers on soil properties and growth of pigeon pea. Scientia Horticulturae 226:1-9.

AOAC, 2012. Official Methods of Analysis, 17th edition. Association of Official Analytical Chemists, Washington D. C., USA.

Atakoun, A. M., P. G. Tovihoudji, R. V. Diogo, P. L. Yemadje, O. Balarabe, P. I. Akponikpè, E. Sekloka, A. Hougni and P. Tittonell. 2023. Evaluation of cover crop contributions to conservation agriculture in northern Benin. Field Crops Research 303:109118.

Atanassova, M., S. Georgieva and K. Ivancheva. 2011. Total phenolic and total flavonoid contents, antioxidant capacity and biological contaminants in medicinal herbs. Journal of the University of Chemical Technology & Metallurgy 46:1

Barry, T. N. and D. A. Forss. 1983. The condensed tannin content of vegetative *Lotus pedunculatus*, its regulation by fertilizer application, and effect upon protein solubility. Journal of the Science of Food and Agriculture 34:1047-1056.

Behera, D. K., R. K. Mohanty and U. Dash. 2020. Cyclicality of public health expenditure in India: role of fiscal transfer and domestic revenue mobilization. International Review of Economics 67:87-110.

Catchpoole, D. W. and G. J. Blair. 1990. Forage tree legumes. II. Investigation of nitrogen transfer to an associated grass using a split-root technique. Australian Journal of Agricultural Research 41:531-537.

Chemists, Association of Official Analytical (US), A. of O. A. C. 2000. Official methods of analysis of the Association of Official Analytical Chemists (Vol. 2). The Association.

Chen, Y., N. Zhu, X. Chen, G. Liu, Y. Li, Y. Guo, M. Deng, D. Liu and B. Sun. 2019. Evaluation of pigeon pea leaves (*Cajanus cajan*) replacing alfalfa meal on growth performance, carcass trait, nutrient digestibility, antioxidant capacity and biochemical parameters of rabbits. Journal of Animal Physiology and Animal Nutrition 103:1265-1273.

Daniel, J. N. and C. K. Ong. 1990. Perennial pigeonpea: a multi-purpose species for agroforestry systems. Agroforestry Systems 10:113-129.

Dzowela, B. H., L. Hove, J. H. Topps and P. L. Mafongoya. 1995. Nutritional and anti-nutritional characters and rumen degradability of dry matter and nitrogen for some multipurpose tree species with potential for agroforestry in Zimbabwe. Animal Feed Science and Technology 55:207-214.

Ella, A., C. Jacobsen, W. W. Stür and G. Blair. 1989. Effect of plant density and cutting frequency on the productivity of four tree legumes. Tropical Grasslands 23:28-34.

Foster, J. L., A. T. Adesogan, J. N. Carter, A. R. Blount, R. O. Myer and S. C. Phatak. 2009. Intake, digestibility, and nitrogen retention by sheep supplemented with warm-season legume hays or soybean meal. Journal of Animal Science 87:2891-2898.

Galang, M. C., R. C. Gutteridge and H. M. Shelton. 1990. The effect of cutting height and frequency on the productivity of *Sesbania sesban var. nubica* in a subtropical environment. Nitrogen Fixing Tree Research Reports 8:161-164.

Geleti, D., M. Hailemariam, A. Mengistu and A. Tolera. 2014. Biomass yield potential and nutritive value of selected Alfalfa (*Medicago sativa L.*) cultivars grown under tepid to cool sub-moist agro-ecology of Ethiopia. E3 Journal of Agricultural Research and Development 4:7-014.

Getachew, G. 1999. Tannins in tropical multipurpose tree species: localisation and quantification of tannins using histochemical approaches and the effect of tannins on in vitro rumen fermentation. University Hohenheim.

Godoy, R. and L. A. R. Batista. 1997. Study of tannin content on forage pigeon-pea (*Cajanus cajan (L*.) Millsp) germplasm. Revista Da Sociedade Brasileira De Zootecnia-Journal Of The Brazilian Society Of Animal Science 26:443-446.

Henderson, E., X. Turrillas and P. Barnes. 1995. The formation, stability and microstructure of calcium sulpoaluminate hydrates present in hydrated cement pastes, using in situ synchrotron energy-dispersive diffraction. Journal of Materials Science 30:3856-3862.

Jabessa, T. and K. Bekele. 2021. Evaluation of Improved Pigeon pea (Cajanus cajan) Varieties at Adola, Guji Zone of Oromia. Advances in Biochemistry 9:1.

Kim, M. and K. Sung. 2023. Assessment of weather events impacts on forage production trend of sorghum-sudangrass hybrid. Journal of Animal Science and Technology, 65:792-803.

Lorusso, L., K. Lacki and Z. Duvnjak. 1996. Decrease of tannin content in canola meal by an enzyme preparation from Trametes versicolor. Biotechnology Letters 18309-314.

Makkar, G. Francis and K. Becker. 2007. Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems. Animal 1:1371-1391.

Makkar, H. P. S., M. Blümmel, N. K. Borowy and K. Becker. 1993. Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. Journal of the Science of Food and Agriculture 61:161-165.

McDowell, L. R. 2003. Mineral in animal and human. 2nd EdElsevier. The Netherlands.

Mekonen, T., A. Tolera, A. Nurfeta, B. Bradford, S. Yigrem and J. Vipham. 2022. Effects of pigeon pea leaves and concentrate mixture on feed intake, milk yield, and composition of crossbred dairy cows fed native pasture hay. Animal 16:100632.

Mishra, V., S. Aadhar, A. Asoka, S. Pai and R. Kumar. 2016. On the frequency of the 2015 monsoon season drought in the Indo-Gangetic Plain. Geophysical Research Letters 43:12-102.

Mueller-Harvey, I. 2006. Unravelling the conundrum of tannins in animal nutrition and health. Journal of the Science of Food and Agriculture 86:2010-2037.

Muir, J. P. 2011. The multi-faceted role of condensed tannins in the goat ecosystem. Small Ruminant Research 98:115-120.

Phatak, S. C., R. G. Nadimpalli, S. C. Tiwari and H. L. Bhardwaj. 1993. Pigeonpeas: Potential new crop for the southeastern United States. New Crops. Wiley, New York, 597-599.

Porter, L. J., L. N. Hrstich and B. G. Chan. 1985. The conversion of procyanidins and prodelphinidins to cyanidin and delphinidin. Phytochemistry 25:223-230.

Radkowski, A., J. Bocianowski, K. Nowosad, E. Piwowarczyk, E. Bakinowska, I. Radkowska and K. Wolski. 2020. Comparison of the yield and chemical composition of eleven timothy (Phleum pratense L.) genotypes under three locations in Poland. Agronomy 10:1743.

Rao, S. C., S. W. Coleman and H. S. Mayeux. 2002. Forage production and nutritive value of selected pigeonpea ecotypes in the southern great plains. Crop Science 42:1259-1263.

Ratnawaty, S. and S. Chuzaemi. 2013. Production and nutritive value of shrub legumes in west timor, east nusa tenggara province Indonesia. Journal of Agricultural Science and Technology 3:349.

Rios-Gonzalez, K., L. Erdei and S. H. Lips. 2002. The activity of antioxidant enzymes in maize and sunflower seedlings as affected by salinity and different nitrogen sources. Plant Science 162:923-930.

Saddul, D., Z. A. Jelan, J. B. Liang and R. A. Halim. 2004. The potential of mulberry (Morus alba) as a fodder crop: The effect of plant maturity on yield, persistence and nutrient composition of plant fractions. Asian-Australasian Journal of Animal Sciences 17: 1657-1662.

Sanbongi, C., N. Osakabe, M. Natsume, T. Takizawa, S. Gomi and T. Osawa. 1998. Antioxidative polyphenols isolated from Theobroma cacao. Journal of Agricultural and Food Chemistry 46:454-457.

Schiavone, A., K. Guo, S. Tassone, L. Gasco, E. Hernandez, R. Denti and I. Zoccarato. 2008. Effects of a natural extract of chestnut wood on digestibility, performance traits, and nitrogen balance of broiler chicks. Poultry Science 87:521-527.

Tabacco, E., G. Borreani, G. M. Crovetto, G. Galassi, D. Colombo and L. Cavallarin. 2006. Effect of chestnut tannin on fermentation quality, proteolysis, and protein rumen degradability of alfalfa silage. Journal of Dairy Science 89:4736-4746.

Tenakwa, E. A., A. Z. Imoro, T. Ansah and F. Kizito. 2022. Pigeon pea (*Cajanus cajan*) fodder cutting management in the Guinea Savanna Agro-Ecological Zone of Ghana. Agroforestry Systems 96:1-10.

Tolera, A., A. Yami and D. Alemu. 2012. Livestock feed resources in Ethiopia: Challenges, Opportunities and the need for transformation.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for Dietary Fiber, Neutral Detergent Fiber, and

Nonstarch Polysaccharides in Relation to Animal Nutrition. Journal of Dairy Science 74:3583-3597.

Vitti, D., A. L. Abdalla, I. C. S. Bueno, J. C. S. Filho, C. Costa, M. S. Bueno, E. F. Nozella, C. Longo, E. Q. Vieira and S. L. S. Cabral Filho. 2005. Do all tannins have similar nutritional effects? A comparison of three Brazilian fodder legumes. Animal Feed Science and Technology 119:345-361.

Yaméogo, C. W., M. D. Bengaly, A. Savadogo, P. A. Nikiema and S. A. Traore. 2011. Determination of chemical composition and nutritional values of Moringa oleifera leaves. Pakistan Journal of Nutrition 10:264.