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Nutrient content of jack bean (Canavalia ensiformis) at different growth stages in Blora, East Java, Indonesia

Bayu Prasetyo[1], *Bambang* Suwignyo[1], *Genki* Ishigaki[2], *Takahiro* Gondo[3], *Diafan* Kurnia Jati[4] and *Yogi* Sidik Prasojo[1*]

[1]Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia
[2]Sumiyoshi Livestock Science
[3] Frontier Science Research Center, University of Miyazaki, 1-1 Gakuen Kibanadai-nishi,
[4]Miyazaki,889-2192,Japan
Pertamina Foundation, Pertamina Learning Center, South Jakarta, Jakarta 12220, Indonesia

Abstract. This study aims to determine the effect of harvesting at different growth stages on nutrient content of jack bean plants cultivated in alluvial type of soil at Blora, Central Java, Indonesia. A field experiment was conducted using a completely randomized block design with four replications. Plant in every plot were randomly selected and hand separated. Each component was sampled approximately 1000 g. Data were analyzed using Analysis of Variance (ANOVA) and continued with Duncan's Multiple Range Test ($p<0.05$). The following parameter observed were nutrient content include dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), dan ether extract (EE). The result showed that growth stages had a significant effect ($P<0,05$) on DM and CF, very significantly ($P<0,01$) on OM and CP, while the CF and EE not significantly ($P>0,05$). DM and CF content increased during the flowering growth stage. On the other hand, the OM content increased as the growth stage increased. However, the CP and EE content decreased as growth stages increased. The vegetative stage is considered the best harvesting stage because it has the highest crude protein content, as leguminous plants are forage plants and an important source of protein for ruminant feed.

1 Introduction

Ruminant livestock are a type of livestock with the unique characteristic of having a stomach consisting of four compartments: the reticulum, rumen, omasum, and abomasum. This uniqueness enables ruminants to utilize forage-based feed to meet their basic maintenance, production, and reproduction needs. Generally, ruminant livestock are fed forage in the form of grasses, which have low protein content [1], necessitating the use of forage with higher protein content. One type of forage that can serve as a protein source for ruminants is legumes.

* Corresponding author: yogi.sidik.p@ugm.ac.id

Indonesia is a country rich in local legume plant resources, have great potential, and many of which remain under-researched. One potential legume plant is jack bean (*Canavalia ensiformis*). Jack bean is a crop distributed across tropical regions and has demonstrated good adaptability, including in Indonesia. Jack bean is a diversified crop with several advantages, including drought tolerance, resistance to pests, high productivity, and versatility for various uses such as direct food consumption, raw material for the food industry, pharmaceutical industry, livestock feed, and as green manure [2]. The productivity of jack bean seeds is relatively high compared to soybeans, with yields of 8–9 tons/ha and 1.2–2 tons/ha, respectively [2]. Jack bean seeds contain nutrients including moisture 7.57%, protein 32.02%, fat 3.83%, ash 4.39%, crude fiber 5.01%, and carbohydrates 46.29%, with seeds sourced from the Genetic Resources Unit of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria [3].

Jack bean plants can grow up to 2000 meters above sea level in tropical areas with temperatures ranging from 20 to 32°C. These plants can thrive in dry areas due to their deep root systems, which allow them to absorb more water compared to grasses. In addition to their seeds, jack bean plants offer other potential uses, particularly for ruminant feed, through their biomass. The biomass yield of Canavalia ensiformis is approximately 21.81 tons/ha fresh weight and 11.29 tons/ha dry matter under tropical environmental conditions, with annual rainfall of 1200 mm and temperatures between 19–33°C [4].

Legume plants generally undergo three growth stages: vegetative, flowering, and pod-setting. The vegetative stage is the period of intensive growth involving vegetative organs such as leaves, stems, and roots. The flowering stage, or the emergence of flowers, marks the transition from the vegetative stage to the opening of the first flower. The pod-setting stage is the period from the end of flowering to the filling of pods on the oldest flower cluster [5]. Harvesting at different growth stages of legume plants impacts their morphological characteristics and nutrient composition [6].

Research on the utilization of jack bean (*Canavalia ensiformis*) as feed for ruminants is still limited both in Indonesia and internationally. The productivity and quality of jack bean plants are influenced by several factors, such as environmental conditions and the growth stage at the time of harvest. Harvesting at different growth stages of jack bean plants could be a breakthrough for the livestock industry in utilizing jack bean as a forage feed source of protein beneficial for ruminants. Therefore, this study aims to determine the effect of harvesting at each growth stage on the dry matter production and nutrient content of jack bean plants.

2 Materials and methods

2.1 Plant materials and experimental site

Jack bean (Canavalia ensiformis) Setren accession seeds were used as plant material for this study. The study was carried out at an elevation of 100 meters above sea level in Megeri Village, Kradenan District, Blora Regency, Central Java (7º21’40’’S 111º26’36’’E) (Figure 1). Most of the land in Blora Regency is dry land. The soil type characterized as alluvial. The climate of Blora Regency is tropical climate, relatively high temperatures in the dry season and sufficient rainfall in the rainy season. Precipitation and air temperature data for the location in 2023 (Figure 2) were obtained from the Ministry of Public Works and People's Housing (PUPR) Bengawan Solo Data for Ngawi Regency, East Java (URL: Sistem Informasi Hidrologi & Kualitas Air (bbws-bsolo.net)).

Table 1. Soil characteristics and physical properties in the experimental site

Soil Parameters[1]	Value
pH (H_2O)	7,59
C Organic (%)	0,50
N Total (%)	0,12
Available P (ppm)	1,33
Available K (Me%)	0,72

[1]C: carbon; N: nitrogen; P: phosphorus; K: potassium

2.2 Climatic condition

The precipitation and average air temperature during the research in 2023 can be seen in Table 1. The lowest rainfall during the crop maintenance period occurred in September and the highest in November, while the lowest and highest air temperatures occurred in September and October, respectively.

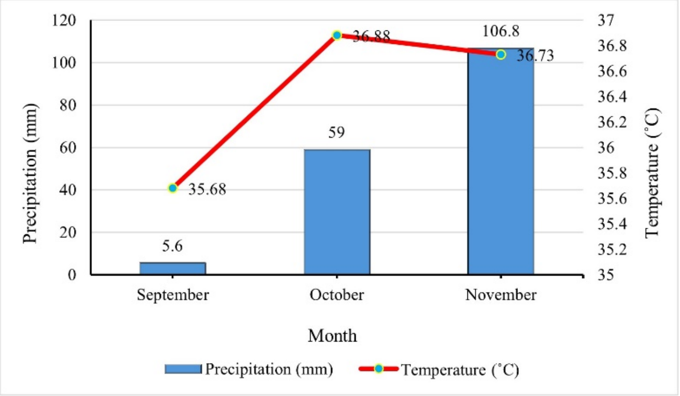

Fig. 1. Climate conditions in term of precipitation and temperature at the experimental site

2.3 Experimental design and cultivation

Planting was carried out for 55 day after planting (DAP) (vegetative), 70 DAP (flowering), and 90 DAP (pod-setting) from September to November 2023. The research area employed a randomized block design with three treatments and four replications. Each replication consisted of plots measuring 1 m^2 (1x1 m) with a total of 12 plots and a spacing of 0.5 m between plots, comprising three growth stages: vegetative, flowering, and pod development. Planting was done by making holes in the soil approximately 2-3 cm deep, with one jack bean seed planted per hole at a spacing of 25x25 cm, in 4 rows, resulting in a plot density of 16 seeds/m^2. Plant maintenance included watering and weeding, with watering conducted once a day at 05:00 AM if there was no rainfall, and weeding done weekly.

2.4 Measurement of cutting and yield

The plant sample cutting was performed 14 cm from the soil surface in different plant growth stages, vegetative (55 DAP), flowering (70 DAP), and pod-setting (90 DAP). The cut plants were then weighed using a hanging scale to obtain fresh weight (leaves and stems). Each component was sampled approximately 1000 g and put into a paper bag and then oven-dried at 55^{o}C for 4 days and weighed back to obtain the dry weight. Dried samples were ground to pass a 1.0 mm screen using a Wiley mill and then stored individually inside the sealed plastic bag based on the treatment. Ground samples were used for further laboratory analysis.

2.5 Laboratory analysis

The chemical analysis of nutrient content included dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), and ether extract (EE) was conducted based on [7].

2.6 Statistical analysis

Statistical analysis was used to compare the results of morphological characteristics and biomass production among different growth stages. The data were statistically analysed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) if significant differences were found (at a significance level of 95%) using SPSS 23.0 (SPSS Inc., USA).

3 Result and Discussion

The analysis results of the nutrient content of jack bean (*Canavalia ensiformis*) plants at each growth stage include dry matter, organic matter, crude protein, crude fiber, and ether extract. The data on the differences in nutrient content of jack bean plants at different growth stages can be seen in Table 2.

Table 2. Nutrient content in jack bean (*Canavalia ensiformis*) at different growth stage (Means±SE)

Nutrient (%)	Growth Stage		
	Vegetative	Flowering	Pod-setting
Dry matter	$20{,}941^{a}\pm0{,}312$	$22{,}098^{b}\pm0{,}419$	$20{,}168^{a}\pm0{,}320$
Organic matter*	$83{,}577^{a}\pm0{,}323$	$85{,}813^{b}\pm0{,}763$	$87{,}350^{b}\pm0{,}348$
Crude protein*	$21{,}656^{b}\pm0{,}746$	$17{,}276^{a}\pm0{,}524$	$17{,}320^{a}\pm0{,}686$
Crude fiber	$19{,}910^{a}\pm0{,}407$	$21{,}946^{b}\pm0{,}599$	$19{,}392^{a}\pm0{,}717$
Ether extract^{ns}	3,675±0,665	3,204±0,962	2,818±0,910
Total digestible nutrient*	$54{,}147^{a}\pm0{,}931$	$53{,}490^{a}\pm0{,}722$	$60{,}593^{b}\pm1{,}512$

^{ns} : non significant
^{ab} : Different superscripts on the same line indicate significant differences (P<0,05)
* : Different superscripts on the same line indicate highly significant differences (P<0,01)

The analysis of the total dry matter content of jack bean (*Canavalia ensiformis*) plants showed different results between leaves and stems. The total dry matter content increased during the flowering growth stage (22.098%) compared to the vegetative stage (20.941%), and then significantly decreased (P<0.05) during the pod-setting stage (20.168%). In the early reproductive stage, such as flowering, the production of leaves and stems reaches its peak before entering the pod-setting stage. [8] stated that in legumes during the early reproductive stage, such as flowering, the photosynthetic products generated by the leaves are distributed and utilized for the formation of primary leaves and stems, thereby increasing the plant's dry matter content. [6] stated that harvesting legume plants, such as soybeans, should be conducted before entering the R7 stage, when one of the pods on the main stem begins to turn brown. Once the plant has entered this stage, the number of leaves and branches decreases, leading to a reduction in dry matter content. Furthermore, the stems become hard and woody, reducing the quality of legumes used as forage crops.

The analysis of total organic matter content showed a highly significant increase (P<0.01) with the advancement of growth stages in jack bean (*Canavalia ensiformis*) plants. This is attributed to the decomposition of plant parts that detach, thereby enhancing soil nutrient content, such as soil organic carbon. [9] stated that soil organic carbon content is crucial for plants, especially for their nutrient content. Soil organic carbon, such as humus and other organic compounds, serves as the primary energy source for soil microbes. Soil microbes play an important role in the decomposition process of organic matter, which produces essential nutrients like nitrogen and phosphorus. [10] noted that one example of soil microbes involved in the decomposition of organic matter is arbuscular mycorrhizal fungi (AM). These fungi play a role in accelerating the decomposition process of organic matter through enzymatic activity and releasing nutrients from organic matter, such as inorganic nitrogen and phosphorus, which can then be utilized by plants. These nutrients become available and can be absorbed by plants for the formation of plant organic matter through the process of photosynthesis.

The analysis results showed that the crude protein content in leaves and total crude protein significantly decreased (P<0.01) as the growth stage of jack bean (*Canavalia ensiformis*) plants progressed. The highest results were obtained during the vegetative stage, with a decrease observed in the flowering and pod-setting stages. These findings align with studies on soybean plants [6], sunn hemp (*Crotalaria juncea*) [11], alfalfa [12], and pigeon pea (*Cajanus cajan*) [13], which showed that crude protein content in leaves and total decreased with advancing growth stages or later cutting ages. This decline can be attributed to the fact that, during the vegetative stage, jack bean plants store a significant amount of crude protein from photosynthesis, which is distributed to plant organs, particularly the leaves. The high protein content in the leaves during the vegetative stage contributes to the total crude protein content in the same stage. These results are consistent with findings by [14], who reported that alfalfa plants in the vegetative growth stage exhibited the highest crude protein content, which decreased with advancing growth stages. During the vegetative stage, legume plants produce more protein through photosynthesis, resulting in higher protein content. [15] stated that, during the reproductive stage to maturity, protein content decreases due to a reduction in leaf and stem production. As the flowering stage begins, nitrogen stored during the vegetative stage is redistributed to other parts of the plant for the formation of flowers and pods, leading to a decrease in the proportion of crude protein (NPN) in the plant.

The analysis results of the total fiber content of jack bean (*Canavalia ensiformis*) plants showed significant differences (P>0.05) at each growth stage. The highest results were obtained at the flowering stage compared to the vegetative and pod-setting stages. The increase in crude fiber content during the flowering stage was due to the proportion of structural tissue in the stem and leaves. The proportion of structural tissue is greater in the stem than in the leaves, which are mostly occupied by thin-walled mesophyll cells during plant maturation. High fiber content can lead to a decrease in digestibility, resulting in less fermentable energy for ruminant animals. In general, leaves are more digestible because they have fewer cell-wall constituents than stems, so the increase in forage value depends on the proportion of plant parts. The crude fiber content in the stems was higher than in the leaves of jack bean plants. This is due to the high lignification process during plant development, which mainly occurs in the stem, resulting in higher crude fiber content in the stem. Lignin composition is very limited at the early stages of development and begins to mature as the plant ages. Lignin composition increases in the middle lamella's main wall area, which is the least digestible part. The fraction of lignified tissue in legumes increases over time as the stem grows [11].

The results of the total ether extract content analysis showed no significant differences (P>0.05) at each growth stage. However, there was a trend of decreasing ether extract values as the growth stage advanced, with the highest results observed during the vegetative stage.

This could be attributed to the leaf-to-stem ratio at each growth stage. [11] stated that leaves of leguminous plants are high in protein and fat content. Therefore, the proportion of leaves greatly influences the ether extract content in plants. [16] reported that ether extract content in plants is determined by the leaf ratio, as the fat and protein in forages mostly originate from the leaves. The ether extract content in plants is correlated with crude protein. The ether extract and crude protein contents in leguminous plants tend to decrease as the growth stage progresses. This aligns with the results of the total crude protein content analysis shown in Table 2.

In conclusion, The dry matter and crude fiber content increased during the flowering growth stage. On the other hand, the organic matter content increased as the growth stage of the plant progressed. However, the crude protein and ether extract content decreased with the advancement of the growth stage. The vegetative growth stage is considered the best harvesting stage because it has the highest crude protein content, as leguminous plants are forage plants and an important source of protein.

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