Agronomic performance, biomass production, and nutrient value of three napier grass cultivars (*Pennisetum purpureum*) in highland area

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Abstract. The study aims to determine the agronomic performance, biomass production, and nutrient value of three *Pennisetum purpureum* cultivar (Biovitas, Pakchong, and Mott) in 1000 meters above sea level (asl) highland area of Petungkriyono, Pekalongan, Central Java, Indonesia. The grasses were planted using vegetative stems and maintained for four months, following completely randomized design (CRD) with four replications for each cultivar. Agronomic performance was assessed before harvested. Napier grass was harvested to investigate the biomass production and nutrient values, including organic matter, crude protein, crude protein yield, crude fibre, and crude fat. Pakchong had the highest biomass and crude fiber content. Biovitas exhibited the highest agronomic performance, with superior plant height, leaf length, leaf width, and stem diameter, as well as the highest nutrient values in term of organic metters. Mott showed the highest tiller number and crude protein content among the cultivars. The distinct strength of each cultivar indicates their potential suitability for various agricultural applications in highland regions.

1 Introduction

Napier grass (Pennisetum purpureum Schumach.), commonly known as elephant grass, is widely recognized for its adaptability, robust biomass production, and high nutritional value, making it a versatile crop in various agricultural systems. Originating from tropical regions, Napier grass has shown significant promise in highland areas, where challenging environmental conditions such as low temperatures, high rainfall, and sloping terrains demand resilient plant species. Its adaptability to diverse ecological zones, particularly highland regions, positions it as a key resource for sustainable agricultural practices [1,2].

Highland areas are prone to soil erosion due to steep slopes and frequent rainfall, which can lead to land degradation and reduced agricultural productivity. The highland areas, such

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as Petungkriyono in Pekalongan, Central Java, are known for their favorable conditions for growing forage crops. This sub-district, located between 500 m and 2100
m above sea level and covering 7358.5 ha, including 5190 ha of forests, lies in the western part of the Dieng Mountains [3,4]. The sub-district's forests are divided into three categories: conservation forests, limited production forests and production forests. There is around 2000 ha of production forests in Petungkriyono, planted with pine trees cultivated for their resin [5]. Napier grass is C4 tropical grasses that plays a critical role in combating soil erosion by acting as a natural barrier. Its extensive root system stabilizes the soil, while its dense foliage helps reduce the impact of raindrops, preventing soil displacement and improving water infiltration. The C4 grass could also cultivate with legume that improve their nutrient content and environment sustainability [6]. Thus, the cultivation of tropical grasses in these areas not only conserves soil but also enhances water management [7,8].

In addition to its ecological benefits, Napier grass is a highly valuable forage crop. It is widely used as a primary feed for livestock due to its high biomass yield and nutrient content. The grass is contained essential nutrients such as crude protein, making it an important feed resource for ruminants in highland farming systems, where maintaining livestock productivity can be challenging due to limited pasture options [1,8]. The cultivars of plants can have an impact on both the quality and quantity of the plant. A study on napier grass found that different planting density and its cutting management had different on nutrient and quantity yield of harvested plant [9,10,11]. Another study on Brachiaria grass found that different species and cultivar lead to different morphology and nutrient content [12]. Different varieties of napier grass can have varying levels of nutrient content.

This study evaluates the agronomic performance, biomass production, and nutrient value of three Napier grass cultivars in a highland environment. By assessing their adaptability and contribution to both soil conservation and livestock feeding, this research aims to provide valuable insights to select the primary cultivar of Napier grass for highland areas.

2 Methodology

2.1 Plant material

Three cultivars of napier grass namely *Pennisetum purpureum* cultivar Biovitas, Pakchong, and Zanzibar were used in this study. Grasses were cultivated using stem cuttings approximately 15 cm.

2.2 Field experiment

The study was conducted from November 2022 to February 2023 in Yosorejo Village, Petungkriyono, Pekalongan Regency, Central Java (7º09’42’’S 109º43’52’’E, elevation of 1000 m above sea level). The soil type characterized as Andosol. Petungkriyono is located in conservation forest with diversed plant species. Yosorejo village in Petungkriyono has low temperatures, high rainfall, and sloping terrains. The fertilizer was done 2 week after cultivation using NPK 15:15:15, 150 kg/ha/year. Plant cultivation maintained for 4 months using a completely randomized design with 4 replications for each cultivar.

2.3 Investigation on morphology

During the cultivation period, morphological characteristics were observed, including plant height, leaf length, leaf width, stem diameter, first collar length, and tiller numbers. Plant was

harvested after 4 month of cultivation and determine for biomass production and nutritional value of grass.

2.4 Statistical analysis

Statistical analysis was conducted to compare the agronomic performance, biomass production, and nutrient content among cultivars. Differences in mean were evaluated by Duncan's Multiple Range Test (DMRT) using SPSS version 25.0.

3 Result and discussion

3.1 Agroclimatic condition

The total precipitation and average temperature during growth period of Napier grass is shown in Figure 1 below.

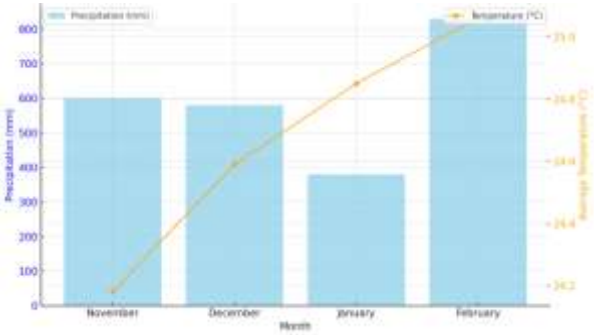

Fig. 1. The monthly precipitation and temperature in Yosorejo Village, Petungkriyono, Pekalongan [13]

The total precipitation was around 600 mm, 580 mm, 380 mm, and 830 mm from November 2022 to February 2023, respectively. November and December had similar levels of rainfall, while February experienced a sharp increase in precipitation, and January had the least amount of rainfall among these months. The implications of precipitation on plant growth are multifaceted, affecting water availability, nutrient uptake, root development, and overall plant physiology. Water is crucial for photosynthesis. Study in shallot cultivation on dry land in Lampung stated that water is essential for dissolving and activating fertilizer, enabling nutrient absorption by plants [14].

The temperature steadily increases from 24.18°C in November to 25.06°C in February. These temperatures are within the optimal range for Napier grass, which typically thrives in temperatures between 25°C to 35°C. This slight temperature increase is generally conducive to growth but needs to be supported by adequate water availability. Low temperatures slow down metabolic activities, particularly photosynthesis, which directly affects the growth rate of grasses. When temperatures fall below the optimal range, the rate of photosynthesis decreases, reducing biomass production [15].

The high precipitation in November, December, and February, combined with moderate temperatures, may supports excellent growth and biomass production. However, the lower rainfall in January could lead to water stress, limiting the grass's productivity unless managed with irrigation. Farmers need to account for these seasonal variations in rainfall and temperature to maximize forage production, particularly by implementing irrigation during drier months and ensuring adequate drainage during wetter periods.

3.2 Agronomic performance

The agronomic performance of Napier grass in highland regions is essential for assessing its adaptability and potential as forage crop, particularly in environments where conditions like soil type, rainfall, and temperature vary significantly. The agronomic performance such as plant height (PH), leaf length (LL), leaf width (LW), stem diameter (SD), first collar height (FCH), and the tiller number (TN) were showed in Table 1.

Table 1. Agronomic performance of three Napier grass cultivars (mean±SD) Morphology Characteristic Cultivars

Morphology Characteristic	Cultivars		
	Biovitas	Pakchong	Mott
PH (cm)*	298,8±13,4[c]	271,8±17,7[b]	119,9±10,5[a]
LL (cm)*	99,3±3,6[b]	92,5±8,6[b]	62,4±1,9[a]
LW (cm)*	4,1±0,1[b]	4,1±0,3[b]	3,1±0,1[a]
SD (mm)[ns]	19,4±1,2	18,3±1,1	16,6±2,0
FCH (cm)[ns]	30,5±7,5	23,5±7,5	18,2±1,0
TN*	6,0±1,2[a]	7,0±2,2[a]	14,0±1,6[b]

[ns]not significant
*superscripts within the same row indicate highly significant difference (P<0.01)

Biovitas and Pakchong exhibit significantly greater plant heights (298.8 cm and 271.8 cm, respectively) compared to Mott (119.9 cm). This indicates that Biovitas and Pakchong have more vigorous growth and biomass potential, which is important in environments where plants need to outcompete other species for sunlight. Both Biovitas and Pakchong have similar and significantly larger leaf lengths and widths compared to Mott, which contributes to greater photosynthetic efficiency and biomass production. This analysis, supported by the findings of Rahman et al [15] and other recent studies, provides a clear understanding of how these morphological traits affect the suitability of Napier grass cultivars in various agricultural settings.

Mott has a higher tillering number (14), which suggests it may have a more robust clonal spread. However, this doesn't translate into greater height or biomass production, which limits its use where large quantities of fodder are required. Study of Napier grass in Ethiopia showed that the different of tiller numbers may differs regarding the genetic variation and interaction to the environment [16].

3.3 Biomass production

Biomass production can indicate how a grass species well adapts to the specific climatic condition found at highland or high altitude. The biomass production of Napier grass after defoliation including fresh matter yield (FMY), dry matter yield (DMY), organic matter yield (OMY), crude protein yield (CPY), and total digestible nutrient yield (TDNY) were shown in Table 2.

Table 2. Biomass production of three napier grass cultivars (mean±SD)

Production (ton/ha)	Cultivars		
	Biovitas	Pakchong	Mott
FMY[ns]	62,4±13,9	66,5±42,3	56,3±18,7
DMY[ns]	9,4±1,9	10,1±6,9	5,1±1,4
OMY[ns]	49,1±10,6	52,3±33,6	42,0±13,3
CPY[ns]	8,2±1,9	9,7±5,6	6,6±2,2
TDNY[ns]	23,0±4,8	32,8±22,2	24,1±7,2

[ns]not significant

The fresh matter yield (FMY) is a crucial indicator of the total above-ground biomass produced per hectare. Pakchong has the highest FMY (66.5 ton/ha), followed closely by Biovitas (62.4 ton/ha), indicating their superior fresh biomass production potential. Mott produces less fresh biomass (56.3 ton/ha), making it less desirable for regions where maximizing fodder output is essential. Although the differences are not statistically significant, this ranking is consistent with studies that emphasize Pakchong potential for higher fresh biomass yield, particularly under optimal growth conditions [15]. Even though Pakchong consistently produces higher yields across most parameters but also exhibits the most variability. Depending on the growing conditions, this could make it less reliable compared to Biovitas or Mott.

Grasses with high biomass production provide extensive ground cover, which helps in reducing soil erosion by stabilizing the soil structure. In highland areas, where soil erosion can be a significant issue, selecting Napier grass cultivars with high biomass production ensures better soil conservation. The plant residues left behind also contribute organic matter, which improves soil fertility over time [17]. Napier grass is a high-nutrient-demanding crop. For optimal growth and high biomass production, it requires good soil fertility, particularly nitrogen. Regular fertilization or organic manure application is essential, especially in soils with low fertility.

3.4 Nutrient value

Livestock farmers rely on grasses that provide adequate nutrients to support growth, milk production, and overall health. Table 3 below showed the nutrient value such as dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CFi), crude fat (CFa), and total digestible nutrient (TDN) of three Napier grass cultivars after 4 months growth.

Table 3. Nutrient content of three napier grass cultivars (mean±SD)

Nutrient (%)	Cultivars		
	Biovitas	Pakchong	Mott
DM*	15,1±0,8^{b}	14,9±1,2^{b}	9,16±0,6^{a}
OM*	78,8±1,5^{b}	78,4±0,9^{b}	74,98±1,8^{a}
CP^{ns}	13,2±0,4	14,6±3,9	11,68±0,6
CFi*	33,2±2,2^{b}	34,9±1,4^{b}	30,18±1,0^{a}
CFa*	3,7±0,5^{b}	2,4±0,5^{a}	2,39±0,2^{a}
TDN*	37,1±4,2^{a}	49,0±3,5^{b}	43,40±3,4^{b}

^{ns}not significant
*superscripts within the same row indicate highly significant difference ($P<0.01$)

Biovitas (15.1%) and Pakchong (14.9%) show higher dry matter percentages compared to Mott (9.16%), suggesting that they offer more nutrient-dense forage per unit weight, which is crucial in highland areas where plant water content might dilute the overall nutritional intake. The Mott cultivar has notably lower DM. indicating higher moisture content. This could be beneficial in areas where water intake from feed is essential, but the lower DM may reduce the total nutrient intake, make it less efficient for nutrient-dense feeding [17].

Although not significantly different, Pakchong has the highest crude protein content (14.6%), making it particularly suitable for livestock requiring high protein intake (such as dairy cattle). Mott has the lowest crude protein content (11.68%), making it less ideal for regions where protein-rich forage is necessary. Optimal crude protein levels in grass allow cows to meet their dietary nitrogen needs, which in turn supports microbial activity in the rumen. This activity enhances the efficiency of nutrient digestion, helping cows produce milk

more efficiently. Crude protein levels between 12-18% in forage are often necessary to support high milk yields [18].

Mott has the lowest crude fiber content (30.18%), which might make it more digestible. Pakchong leads with the highest TDN (49.0%), indicating it provides the most digestible nutrients for livestock, which is essential for high-yield dairy production or beef fattening in highland regions.

In conclusion, for highland areas, where growth conditions are often more challenging, Pakchong should be the primary cultivar selected due to its superior biomass production, high nutrient content, and energy density. Biovitas can be considered as a secondary option, especially in situations where drought resistance or energy-rich fodder is less of a concern. Mott may only be considered in specific circumstances where its higher tillering and lower fiber content offer distinct advantages, but it generally underperforms compared to the other cultivars in terms of overall agronomic performance and nutrient content.

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