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The Effect of Water Application Levels on the Nutritional Value of Maize (*Zea mays* L.) Forage under Biochar-Amended Vertisol Soil in Kupang Regency, East Nusa Tenggara

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ABSTRACT

This study aimed to examine the effect of different water levels on the growth and nutritional value of maize (Zea mays *L.*) *forage grown on Vertisol soil amended with corncob biochar. The research was conducted in Oesao Village, Kupang Regency, East Nusa Tenggara. Biochar was produced by pyrolyzing corncobs at 300–600°C and applied in the soil at 6% by weight. The experiment used a Completely Randomized Design with four water levels (K1 = 100%, K2 = 90%, K3 = 80%, K4 = 70% of field capacity) and six replications for measuring plant growth. Soil property and proximate analyses were conducted using composite samples with three replications. Chemical properties of biochar, initial and post-treatment soil properties, plant growth (height, number, and leaf area), and forage nutritional quality were analyzed. The results showed that treatment K4 improved soil chemical properties including organic carbon, P_2O_5, cation exchange capacity (CEC), and exchangeable cations. Treatment K1 produced the best vegetative growth with the most leaves, leaf area, and plant height. Meanwhile, treatment K3 resulted in the best forage nutritional quality, with the highest nitrogen, crude protein, and crude fat content and the lowest crude fiber content. Overall, treatment K3 was considered the most optimal because it balanced plant productivity and forage quality.*

1. INTRODUCTION

East Nusa Tenggara is one of Indonesia's leading beef cattle producers. Data from the Directorate General of Livestock and Animal Health Services shows that the region supplies cattle to several major cities, including Greater Jakarta (Jabodetabek). The Livestock Service of East Nusa Tenggara Province recorded that in 2024, the number of cattle shipments leaving the province reached 45,670 heads. The three highest supplying regions include Timor Tengah Selatan Regency with 9,704 heads, Kupang Regency with 8,394 heads, and Timor Tengah Utara Regency with 7,885 heads (Antara NTT, 2025).

Beef cattle production in East Nusa Tenggara (NTT) can still be improved by enhancing nutrition, including using forage from maize plants. This forage can be derived from maize biomass, which accounts for approximately 50% of the total plant weight (Farda *et al*., 2020). In NTT, maize is cultivated mainly on drylands covering 3.3 million hectares, many of which consist of Vertisol soils (Mulyani, 2013). However, dryland cultivation often faces drought stress, which negatively affects plant growth and reduces the quality of forage for livestock. Shi *et al*. (2010) explain that water deficiency disrupts plant growth, reduces photosynthesis, and inhibits root development, leading to lower yields and seed quality (Ghazi, 2017). Furthermore, this stress also decreases the nutrient content in maize seeds, affecting their quality (Poudel, 2023).

Adding biochar to the soil is one solution to drought stress. Field studies on vertisol soils in China showed that the combination of tillage and biochar application significantly improved nutrient content (N, P, C, and K), soil microbial structure, and crop yields (Chen *et al*., 2022). Biochar has been proven to enhance vertisol soils' texture and shallow clay layers, increasing water and nutrient retention in the subsoil layers. Further research also revealed that land treated with biochar produced crops with higher yields, a more balanced soil pH, and better nutrient content and water retention than other soil amendments such as compost and chemical fertilizers. Therefore, biochar is the most effective soil amendment in improving soil quality and supporting sustainable agriculture (Al-Fatlawy *et al*., 2025).

One solution to overcome drought stress is the addition of biochar to the soil, which can improve water availability and the nutritional quality of forage. Corn forage is considered an excellent feed source for cattle as it contains high levels of essential nutrients such as carbohydrates, protein, and fat, along with relatively low crude fiber content, making it highly digestible for ruminants (Widiastuti *et al*., 2022). Furthermore, corn leaves and stems can be processed into silage with high moisture content and rich energy values, which is particularly beneficial during the dry season when forage availability is limited (Mulianti, 2024). The enhancement of nutritional components in corn leaves, such as protein and energy content, positively contributes to livestock productivity in terms of growth performance and meat production (Nurtanti *et al*., 2025).

Corncobs are a readily available biochar material around agricultural lands. Referring to the data on the harvested area of maize in Kupang Regency in 2023, which is 11,385 hectares (BPS, 2024), and based on the dry matter formula by Syamsu *et al*. (2003) and Arief *et al*. (2012) in Mulyanti (2025), the potential corncob production in Kupang Regency each year can reach around 1,024.65 tons. The addition of 6% corncob biochar in the soil has positively affected soil chemical properties (Masria *et al*., 2021). In addition, corncob biochar also enhances water availability for plants (Masria *et al*., 2018). Using biochar as a soil amendment in forage production can improve soil fertility by increasing water retention and nutrient availability. Moreover, biochar can improve the nutritional composition of livestock feed, thereby supporting animal growth and health (Nair *et al*., 2023). This research aims to evaluate the effects of different levels of water supply on the growth and nutritional value of maize forage as livestock feed and to determine the optimal water supply level to improve water use efficiency, especially in arid regions. The results of this study are expected to provide scientific information and practical recommendations for farmers and livestock breeders in managing water resources and feed sustainably, thereby improving feed quality, productivity, and the competitiveness of livestock businesses.

2. MATERIALS AND METHODS

2.1. Preparation of Corncob Biochar

Biochar production from corncobs was conducted using a rotary drum apparatus. The process began with chopping and drying the corncobs to reduce their moisture content. Once dried, the chopped cobs were placed into the rotary drum and subjected to pyrolysis at temperatures ranging from 300 °C to 600 °C for four hours. Upon completion of the heating process, the resulting biochar was removed from the reactor and quenched with water to prevent further combustion and potential ash formation. The biochar was subsequently dried for 24 hours and ground to a fine consistency, with particles passing through a 2 mm sieve before its application as a soil ameliorant.

2.2. Soil Sample Preparation

Soil sampling was conducted in Oesao Village, East Kupang District, Kupang Regency, located at coordinates 10.12566° S and 123.81556° E, 51 meters above sea level, and approximately 36 km from Kupang City. The site is characterized by flat to gently undulating land with a slope gradient ranging between 0 % and 3 %. The collected soil samples are classified as Vertisols (Masria *et al*., 2021) and were obtained from a depth of 0–20 cm. After collection, the soil samples were air-dried, ground, and sieved using a 2 mm mesh. Subsequently, 12 kg of soil were placed into polybags, and then treated with corncob biochar at 6% (w/w), equivalent to 720 g, and incubated for two weeks before planting.

2.3. Planting

Maize seeds were sown in polybags measuring 20 × 50 cm, with three seeds planted per bag using the dibble method at 2–3 cm depth. After germination, thinning was performed to retain two healthy plants per polybag for observation.

2.4. Sample Observation

Soil moisture content was regulated by daily weighing the samples according to their respective weights. Irrigation was applied until the plants entered the generative phase, which was marked by the complete emergence of tassels (male flowers), approximately 60 days after planting. Harvesting at 60 days after planting (DAP) was conducted without waiting for the physiological maturity stage of the grains, as at this age, the accumulation of dry matter and the nutritive value of the forage—particularly crude protein and total digestible nutrients (TDN)—are relatively high and considered optimal for ruminant feed (Harianti, 2023).

2.5. Observation Parameters

The chemical properties of the biochar analyzed included: Soil organic carbon (%) using the Walkley-Black method, total nitrogen (%) using the Kjeldahl method, available phosphorus P_2O_5 (ppm) using extraction with Olsen, cation exchange capacity (me/100 g) using extraction using ammonium acetate (NH4OAc) solution, base saturation (%) calculated based on CEC analysis results and content of base cations (Ca^{2+}, Mg^{2+}, K^+, Na^+), exchangeable cations (me/100 g) using extraction with ammonium acetate pH 7, followed by analysis of Ca, Mg, K, Na ions and pH H_2O using a pH meter measurement method. Plant growth components inclding number of leaves, leaf area (cm²), and plant height (cm). The nutritional quality of forage (based on proximate analysis) included: plant dry weight, ash content, nitrogen content, crude fat, and crude fiber.

2.6. Data Analysis

This study utilized a single-factor experimental design, wherein the treatment consisted of four different levels of water application: K1 representing 100% field capacity, K2 at 90% field capacity, K3 at 80% field capacity, and K4 at 70% field capacity. Each treatment was replicated six times. Plant growth parameters were measured individually for all six replications. Composite sampling was employed for the analysis of chemical properties following the treatments and for the proximate analysis of plants. Two replications were combined to form a single composite sample to minimize variability and enhance cost efficiency. Consequently, three composite samples were analyzed per treatment for soil and proximate evaluations. Data were subjected to analysis of variance (ANOVA), and when significant differences between treatments were detected, the least significant difference (LSD) test was applied as a post hoc procedure.

3. RESULTS AND DISCUSSION

3.1. Chemical Properties of Corncob Biochar

The chemical properties of corncob biochar were analyzed to understand the fundamental characteristics of the material used as a soil amendment. These chemical properties play a crucial role in determining the effectiveness of biochar in enhancing soil quality and supporting plant growth. The parameters evaluated included pH, Soil organic carbon content (SOC), and cation exchange capacity (CEC). Data presented in Table 1 indicate that the corncob biochar contains 32.41% organic carbon, 1.55% total nitrogen, a favorable cation exchange capacity, and a neutral to slightly alkaline pH. Despite being produced through a relatively simple pyrolysis process, the biochar proved effective in improving soil fertility, enhancing water retention, and promoting soil microbial activity. A CEC value of 47.16 me/100 g and a pH of 7.9 suggest that the biochar has a strong capacity to retain nutrients essential for plant uptake. These findings are consistent with those reported by Sukmawati (2020) and Rattanaphaiboon *et al*. (2022), who observed that corncob biochar possesses high levels of organic carbon and CEC, making it suitable for soil amendment purposes. Corncob biochar has high levels of organic carbon and CEC, making it ideal for soil amendment.

Table 1. Chemical properties of corn biochar

Property	Unit	Value
Soil Organic Carbon	%	32.41
Total Nitrogen	%	1.55
Cation Exchange Capacity (CEC)	me/100 g	47.16
pH (H_2O)	--	7.9

3.2. Initial Soil Properties

Before applying biochar, an analysis of the soil's initial chemical properties was conducted to establish a baseline for evaluating the treatment's effectiveness. Key chemical parameters, including pH, Soil organic carbon content, concentrations of primary macronutrients (N and P), Base Saturation, and cation exchange capacity (CEC), were assessed to characterize the initial fertility status of soil. These baseline data serve as a critical reference point for identifying changes resulting from the biochar application. The results of the initial soil analysis indicated that the levels of organic carbon and total nitrogen were classified as very low. At the same time, base saturation was high, available phosphorus (P_2O_5) was very high, CEC was high, and the soil pH (measured in H_2O) was neutral. A detailed summary of these findings is presented in Table 2.

Tabel 2. Initial soil chemical properties

Property	Unit	Value	Criteria
Soil Organic Carbon	%	0.51	Very Low
Total Nitrogen	%	0.06	Very Low
Base Saturation	%	71.12	High
P_2O_5	ppm	31.35	Very High
CEC	me/100 g	34.62	High
pH (H_2O)	--	7.31	Neutral

The low levels of organic carbon and nitrogen in Vertisol soils are attributed to a combination of inherent factors and environmental conditions. One of the primary causes is the high smectite clay content (Hamadjida *et al*, 2022), which exhibits significant swelling and shrinking capacity, leading to pedoturbation that accelerates the mineralization of organic matter (Utomo, 2016). Additionally, smectite clay's large specific surface area results in strong binding of organic particles, making them less accessible for microbial decomposition (Prasetyo, 2007; Purwanto *et al.*, 2014). The extreme monsoonal climate also plays a role, as prolonged dry seasons cause deep soil cracking that increases aeration and oxidation of organic matter, while rainy seasons with frequent waterlogging promote denitrification, reducing nitrogen availability (Utomo, 2016).

Physical and chemical properties of vertisol soil also contribute to its low organic matter content. Its heavy clay texture hinders root development and vegetation growth, limiting natural input for organic matter (Utomo, 2016). In addition, intensive tillage practices without incorporating organic amendments accelerate soil organic carbon depletion (Arvienda *et al.*, 2023). From a chemical perspective, the neutral to alkaline soil pH (ranging from 6 to 8.5) promotes the mineralization of organic matter. At the same time, a low C/N ratio (< 12) further accelerates organic matter decomposition (Purwanto *et al.*, 2014). Furthermore, the high cation exchange capacity (30–50 me/100 g) leads to strong adsorption of ammonium ions, thereby reducing nitrogen availability for plant uptake (Prasetyo, 2007).

Table 3. Effect of moisture content on soil chemical properties

Treatment	SOC (%)	TN (%)	P_2O_5 (ppm)	CEC (me/100 g)	EDC (me/100g)	Base Saturation (%)	pH ()
K1	0.55 b	0.07	34.94 b	35.01 c	0.66 c	70.50 b	7.30
K2	0.62 b	0.07	40.24 b	38.73 b	1.03 b	71.53 b	7.27
K3	0.70 a	0.09	51.74 a	40.42 a	1.22 a	81.74 a	7.31
K4	0.79 a	0.10	53.13 a	40.52 a	1.24 a	82.86 a	7.32
p-value	0.0024	0.336	0.0024	0.000	0.000	0.008	0.828
LSD (5%)	0.098	--	8.3	0.091	0.15	7.43	--

Note: Numbers followed by the same letter indicate that the values are not significantly different at the 5% test level.

3.3. Effect of Water Levels on Soil Chemical Properties

Table 3 shows effect of treatments (K1, K2, K3, K4) on the chemical properties of soil. Based on the ANOVA, it can be concluded that the treatments significantly affected ($p < 0.05$) several soil chemical properties. The parameters included soil organic carbon (SOC) with $p = 0.0024$, P_2O_5 ($p = 0.0024$), cation exchange capacity (CEC) ($p = 0.000$), base saturation (p = 0.008), and exchangeable divalent cations (EDC) (p = 0.000). In contrast, total nitrogen content (p = 0.336) and soil pH (p = 0.828) did not show significant differences among treatments, indicating that the treatments did not produce a significant effect on these two parameters.

Overall, treatment K4 (70 % field capacity) demonstrated the most favourable effects on the majority of soil parameters, as reflected by the highest values recorded for soil organic carbon (0.79), P_2O_5 (53.13), CEC (40.52), base saturation (82.86), and exchangeable divalent cations (1.24). This suggests that treatment K4 (70 % field capacity) was the most effective in enhancing the chemical properties of the soil in this study. Although statistically not significantly different for total nitrogen, a decrease in water content appears to increase the percentage of total nitrogen in the soil.

Applying biochar improved soil chemical properties through its unique structural and functional mechanisms. The K4 treatment (70 % at field capacity) yielded the highest results due to several synergistic contributing factors. The application of corncob biochar at a rate of 6% by total soil weight significantly increased the organic carbon content from 3.21% to 3.86% (Masria *et al*., 2021). This increase directly contributed to the enhancement of cation exchange capacity (CEC), as the negative charges on the surface of biochar organic particles enabled the soil to retain more essential cations such as Ca^{2+}, Mg^{2+}, and K^{+} (Kabir *et al*, 2023).

Biochar also plays a significant role in maintaining soil pH at neutral levels, thereby enhancing the availability of nutrients such as phosphorus (Masria *et al*., 2021). The fine porous structure of biochar provides a large surface area for nutrient adsorption, resulting in significantly improved nutrient retention and base saturation. Furthermore, the combination of biochar application with low water levels has increased soil porosity from 56.49% to 69.12% and reduced bulk density from 1.2 g/cm³ to 0.8 g/cm³ (Masria *et al*., 2018). These physical changes directly improve soil aeration, accelerating the mineralisation of organic matter. Such conditions also help reduce nutrient leaching, allowing nutrients to remain available in the soil longer. Therefore, using biochar—particularly under low water conditions—is an effective strategy for improving the soil's chemical and physical quality in an integrated manner. This demonstrates that biochar can significantly enhance soil conditions even under minimal water input.

3.4. Effect of Water Levels on Vegetative Plant Growth

Based on the results of the ANOVA test in Table 4 on three vegetative components of maize plants—number of leaves, leaf area, and plant height—it is evident that moisture content treatment significantly affects maize vegetative growth. This is confirmed by the p-values for all parameters being much lower than 0.05, explicitly p = 0.0028 for number of leaves, and p = 0.000 for leaf area and plant height). This indicates that the differences among moisture content treatments are statistically highly significant. The 5% LSD test also shows that the K1 treatment gave the highest values for all growth components. At the same time, K4 produced the lowest results, suggesting that moisture content treatment strongly determines the optimal vegetative growth of maize. Thus, these data demonstrate that precise moisture content regulation is crucial for increasing the number of leaves, leaf area, and plant height of maize plants. The K1 (100 % Field Capacity) treatment, which has the optimal moisture content, effectively supports maximum vegetative growth, while suboptimal moisture content, such as in K4 (70 % Field Capacity), tends to limit plant development.

Table 4. Effect of moisture content on the vegetative growth of maize plants

Treatment	Vegetative Components of the Plant		
	Number of Leaves	Leaf Area (cm²)	Plant Height (cm)
K1	12.83 a	329.25 a	213.83 a
K2	12.67 a	308.50 b	196.17 b
K3	12.33 a	303.18 c	170.21 c
K4	11.67 b	232.83 d	144.83 d
p-value	0.0028	0.000	0.000
LSD 5%	0.592	1.27	2.07

Numbers followed by the same letter indicate that the values are not significantly different at the 5% test level.

Plants exhibit physiological and morphological responses under drought conditions as adaptive mechanisms to cope with, avoid, or neutralize the adverse effects. Drought stress affects maize's growth, yield, and quality by inhibiting key physiological processes such as photosynthesis and transpiration, ultimately leading to reduced vegetative growth and lower yields (Poudel, 2023). Drought stress has also been shown to reduce chlorophyll content 30 and 60 days after planting and increase proline accumulation in sweet corn (Poudel, 2023). Furthermore, the impact of drought stress on maize growth, development, and yield disrupts essential physiological functions, including photosynthesis, respiration, and nutrient uptake, resulting in diminished vegetative growth (Deribe, 2023).

Plants experiencing water deficiency tend to be smaller than well-watered plants. Water shortage during the vegetative growth stage is often visibly manifested by a reduction in leaf area (Latif *et al.*, 2023). Water stress affects both the physiological and biochemical processes of the plant (Islami & Utomo, 1995), disrupting mitotic activity (cell elongation and expansion), which ultimately leads to reductions in plant height, leaf area, and overall growth (Hussain *et al*., 2021). Soil moisture levels significantly influence the vegetative growth of maize plants. The K1 treatment (100% field capacity) produced the best leaf number, leaf area, and plant height results, followed by K2 (90% field capacity). In contrast, the K4 (70% field capacity) treatment exhibited the lowest growth performance due to drought stress. Water deficiency hampers essential physiological processes such as photosynthesis, respiration, and nutrient uptake, reducing vegetative growth. The impact is evident in the decreased leaf area, plant height, and overall plant size.

3.5. Effect of Water Levels on Proximate Composition

The proximate components analyzed included dry weight, ash content, total nitrogen, crude protein, crude fat, and crude fiber, as shown in Table 5. Based on the analysis of variance (ANOVA) results in the table, moisture content significantly affected several proximate parameters of corn forage, namely dry weight, ash content, crude fat, and crude fiber ($p < 0.05$). Treatment K4 (70% field capacity) yielded the highest values for dry weight and ash content. In comparison, K3 (80% field capacity) showed a relatively high increase in crude fat without an excessive rise in crude fiber content. On the other hand, although nitrogen and crude protein levels did not differ significantly statistically ($p > 0.05$), there was a tendency for an increase in both components with decreasing moisture content. This is evidenced by the gradual increase in nitrogen and crude protein values from treatment K1 (100% field capacity) to K3 (80% field capacity). These findings indicate that biochar application has the potential to enhance nitrogen and crude protein content, consistent with the study by Khan *et al*. (2022), which reported that biochar application can increase nitrogen and protein content in wheat grown on calcareous soils, such as vertisols.

Table 5. Effect of moisture content on proximate test components of corn forage

Treatment	Proximate Test Components (%)					
	Dry Matter	Ash Content	Nitrogen	Crude Protein	Crude Fat	Crude Fiber
K1	18.35 b	10.72 b	1.61	10.07	2.93 b	27.81 a
K2	20.45 b	11.67 b	1.76	10.93	2.57 b	28.31 a
K3	21.51 b	12.99 ab	1.86	11.61	3.40 ab	27.62 a
K4	28.17 a	13.19 a	1.81	11.32	3.64 a	26.12 b
p-value	0.0002	0.012	0.069	0.065	0.018	0.047
LSD	2.76	1.42	--	--	0.63	1.51

Numbers followed by the same letter indicate that the values are not significantly different at the 5% test level.

Considering all the analysed parameters, treatment K3 (80 % field capacity) can be regarded as the best treatment. This treatment produced the highest nitrogen content (1.86%) and crude protein (11.61%) compared to other therapies, supported by high oil fat content that was still within optimal limits. In addition, the crude fiber content in K3 (80 % field capacity) was relatively low, indicating good forage quality for animal feed. Therefore, reducing the moisture content to the level in treatment K3 (80 % field capacity) can enhance the overall nutritional quality of corn forage.

Dry Matter

Dry Matter is a key indicator in assessing plant growth and productivity, as it reflects biomass accumulation resulting from physiological activities such as photosynthesis and respiration. Salisbury & Ross (1992) emphasised that this parameter provides accurate quantitative data related to plant tissue growth. Water availability is an essential factor influencing dry weight, as water plays a role in nutrient dissolution and transport, as well as determining the physiological efficiency of plants. Water deficiency causes a decrease in dry weight due to a reduction in the photosynthesis rate caused by stomatal closure and disrupted nutrient absorption. Wahono *et al*. (2018) research on soybean plants showed that water content significantly affects fresh and dry weight, constituting more than 80% of the fresh weight of plant tissues. Furthermore, Nurjanaty *et al*. (2019) added that dry weight results from the balance between photosynthesis and respiration, which highly depends on water availability and nitrogen content in plant tissues.

Applying biochar has been proven to increase water availability in the soil, ultimately contributing to increased plant dry weight, especially under limited water supply conditions. Biochar has a porous structure with a large surface area, allowing an increase in water retention capacity in the topsoil layer (Agviolita *et al*., 2021; Anwar *et al*., 2024). Besides improving soil physical properties and reducing water loss due to evaporation, biochar also helps maintain stable plant water availability. This supports plants in sustaining growth even under water stress conditions (Nurlaeny *et al*., 2023). Biochar also enhances the root system's water and nutrient absorption efficiency, thereby supporting metabolic and photosynthetic processes. Thus, plants can produce biomass optimally and achieve high dry weight even under water deficiency conditions (Hidayatullah *et al*., 2023; Agviolita *et al*., 2021).

Ash Content

Based on the analysis results, the K4 (70% field capacity) and K3 (80% field capacity) treatments showed the best results in terms of ash content in the feed. Ash content reflects the total amount of inorganic minerals remaining after all organic matter in the feed has been completely burned. According to the Indonesian National Standard SNI 3148.2 (BSN, 2009), the maximum allowable ash content in ruminant feed is 12% of the total material. Ash content is closely related to the mineral content of organic matter. Therefore, a decrease in ash content may indicate an increase in other nutrients such as protein, fat, carbohydrates, and vitamins. Ash in feed also plays a role in identifying essential minerals needed to support animal health, growth, and immunity. The K4 (70% field capacity) treatment, which involved adding 6% biochar, produced the most optimal results in increasing the feed's ash content. Biochar is derived from mineral-rich biomass and processed in preserve its mineral content. Due to these properties, biochar not only increases ash content in feed but also has the potential to enrich mineral content in soil and plant mineral content (Kalus et al., 2019).

Crude Fat

The highest crude fat content was obtained in treatment K4 (70 % field capacity). Crude fat in forage feed is a dense energy source, helps absorb fat-soluble vitamins, and enhances feed palatability. In addition, fat supports various metabolic processes, skin and coat health, and contributes to livestock's overall welfare and productivity. Biochar can improve feed palatability and crude fat intake by altering the physical and chemical properties of the feed and influencing gut microbiota that support fat fermentation. Meta-analysis results show that biochar contributes to increased crude fat levels, which support livestock growth, performance, and health (Qomariyah *et al*., 2023).

Crude Fiber

The analysis showed no significant differences in crude fiber content between treatments K1 (100 % field capacity) and K3 (80 % field capacity); a significant difference was observed with treatment K4 (70 % field capacity), which had the lowest crude fiber level. Crude fiber in forage feed refers to the indigestible fiber portion that remains insoluble in dilute acid or alkali. It consists of cellulose, hemicellulose, lignin, and other structural components of plant cell walls. Crude fiber is essential in supporting livestock digestion, promoting rumen fermentation, maintaining pH balance, and aiding intestinal motility in ruminants and non-ruminants. The crude fiber content in treatment K4 (70 % field capacity) was 26.12%, which is considered adequate for livestock feed. According to Keraf (2019), ideal crude fiber content in the forage ranges from 15% to 33%, depending on the forage type and feed processing methods used to maintain balanced nutritional value.

4. CONCLUSION

The analysis of various parameters—namely soil chemical properties, vegetative growth of maize plants, and proximate composition of maize forage—indicates that each soil moisture treatment (K1, K2, K3, K4) has advantages in different aspects. The K4 (70% field capacity) treatment showed the most favorable results in improving soil chemical properties, such as increasing soil organic carbon, available P_2O_5, cation exchange capacity (CEC), and exchangeable cations, making it highly effective in enhancing soil fertility. Meanwhile, K1 (100 % field capacity), representing the optimal moisture condition, resulted in the best vegetative growth of maize plants, as shown by the highest number of leaves, leaf area, and plant height among all treatments. On the other hand, K3 (80 % field capacity) produced the most favorable outcomes in improving the nutritional quality of maize forage. This treatment resulted in the highest levels of nitrogen, crude protein, crude fat, and lower crude fiber content, making it ideal for producing high-quality forage suitable for animal feed. Considering all the observed parameters, K3 (80 % field capacity) can be regarded as the best overall treatment, as it provides a balance between plant productivity and forage quality.

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