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Optimizing Food and Feed in Maize–Livestock Systems in Northern Ghana: The Effect of Maize Leaf Stripping on Grain Yield and Leaf Fodder Quality

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Abstract: Access to feed for livestock during the cropping season is a constraint to the smallholder crop–livestock farming system in northern Ghana due to backyard farming. A two-year (2017–2018) study was conducted to determine the effect of leaf stripping on yield and feed quality in maize–livestock farming systems in the Northern, Upper East, and Upper West regions of Ghana. A factorial treatment combination of three maize-maturity types (extra-early: Abontem, early: Omankwa, and medium: Obatanpa) and three leaf stripping methods (control, leaf stripping at 50% tasseling, and leaf stripping at 50% silking of maize) were laid out in a strip-plot design with four replications per region. Stripped leaf biomass, grain yield, stover, cob size, and nutritional quality of stripped maize leaf were measured. The stripped leaf biomass, stover, and cob width of Obatanpa increased significantly relative to the other maize types in the Northern and the Upper West regions. Abontem recorded a higher ($p < 0.01$) grain yield than that of the other maize types in the Upper East Region. Leaf stripping had no significant effect on the grain yield and the crude protein (CP) content of maize leaf. The CP of the maize leaf (93–100 g/kg) was above the minimum CP requirement of a quality feed for body weight maintenance of ruminants. This suggests that smallholder maize–livestock farmers could strip maize leaves at either tasseling or silking to feed their livestock during the cropping season in northern Ghana and similar agro-ecological zones in West Africa.

Keywords: feed quality; grain yield; leaf stripping; maize; savanna

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1. Introduction

Mixed farming systems which involve the integration of crops and livestock are common in rain-fed agriculture in Sub Saharan Africa and these systems provide food, income, draft power, transportation, and employment for millions of poor subsistence farmers in the region [1,2]. In West Africa, pearl millet [*Pennisetum glaucum* (L.) R.Br.], sorghum [*Sorghum bicolor* (L.) Moench)], and maize (*Zea mays* L.) are the principal cereals, whereas sheep, goats, and cattle are the dominant livestock in the crop–livestock system [1]. Among these principal cereals, maize has replaced traditional cereals (sorghum and millet) as a major staple even in the dry regions of West Africa due to the availability of early-maturing, stress-tolerant varieties; the higher yield potential of maize under improved management practices; and its ability to fit into different farming systems compared with sorghum and millet [3,4].

In northern Ghana, the maize–livestock farming system is dominated by smallholder farmers with an average maize farm size of less than 2 ha [5] and a small ruminant herd size of 0.90 Tropical Livestock Unit (1 TLU = 250 kg animal live weight) [6,7]. Maize cultivation in northern Ghana uses a low level of technology and inputs, and it involves the use of bullocks or tractors to plough the land and manual labor for planting, weeding, fertilizer application, and harvesting. The inputs used include inorganic fertilizer and certified seeds of open-pollinated maize varieties, although farmers recycle these certified seeds approximately two to three times before buying new seeds due to a high loss of yield and nutritional value in the older seeds [5]. Obatanpa maize (105-day maturity) is the most popular variety among farmers in Ghana [8]. The average yield of maize on farmers' fields in northern Ghana is approximately 1.6 t/ha compared to a potential of 5.5 t/ha [9,10]. This yield gap is caused by several biotic and abiotic factors, and key among them is an increase in erratic rainfall patterns caused by climate change [11,12].

West African Dwarf breeds of sheep and goats (Djallonké) are the main groups of small ruminants kept by most smallholder farmers in northern Ghana, and this is because they are hardy, disease resistant, and prolific [13]. The Djallonké sheep and goats are kept under two main husbandry practices. These include allowing the animals to range freely during the dry season and tethering them on communal or uncultivated land to graze sparse vegetation during the cropping season [13]. Livestock access to quality forage is limited during cropping seasons due to cultivation of crops in compound or backyard farms, which results in tethering of livestock to restrict their feed movement and to avoid damage to crops [6,13,14]. This results in loss of body weight during the cropping season [13]. Some studies have documented the use of maize stover [15,16] and maize leaves harvested prior to physiological maturity (leaf stripping) [17,18] as livestock feed. Maize leaf strippings are nutritious feed with a concentration of high soluble proteins and carbohydrates [17].

Despite the nutritious quality of maize leaf stripping as feed, there are conflicting reports on the effect of maize leaf stripping on grain yield. Whereas some authors have reported a decrease in maize grain yield [19–21], others have reported no difference or an increase in maize grain yield [17,22–24], with maize leaf stripping depending on the time of harvest of the maize leaf. On-farm evaluation of maize leaf stripping as small ruminants feed to determine the appropriate time of stripping the leaves without compromising grain yield in maize–livestock systems need more attention in West Africa, particularly in northern Ghana. This information would be very useful to smallholder maize–livestock farmers in addressing the challenges of adequate and quality feed available to livestock during the cropping season to either maintain or increase their body weight. It would also help to improve the productivity of the crop–livestock system and labor dynamics, as farmers would have to spend less time finding quality feed for the livestock during this period. We hypothesized that maize maturity type and leaf stripping would not affect the nutritional quality of stripped maize leaf, yield, and yield component of maize. This study determined the effect of maize maturity type and leaf stripping on grain and feed yields as well as the nutritional quality of the leaf stripping for feeding livestock in smallholder maize–livestock systems in northern Ghana.

2. Materials and Methods

2.1. Study Area

The experiment was conducted on-farm in Northern (Cheyohi No. 2, Tingoli, Duko, and Tibali communities), Upper East (Samboligo, Nyangua, Gia, and Bonia communities) and Upper West (Zanko, Guo, Goli, and Goriyiri communities) regions of northern Ghana during the 2017 and the 2018 cropping seasons (Figure 1). The three regions have a unimodal rainfall pattern with a total annual rainfall (June–October) of less than 1000 mm (Figure 2). The mean annual minimum and maximum temperatures range from 24 to 38 °C, respectively. The Upper East Region is mainly dry (Sudan) savanna agro-ecology relative to that of the Northern and the Upper West regions which are wet (Guinea) savanna agro-ecology [25].

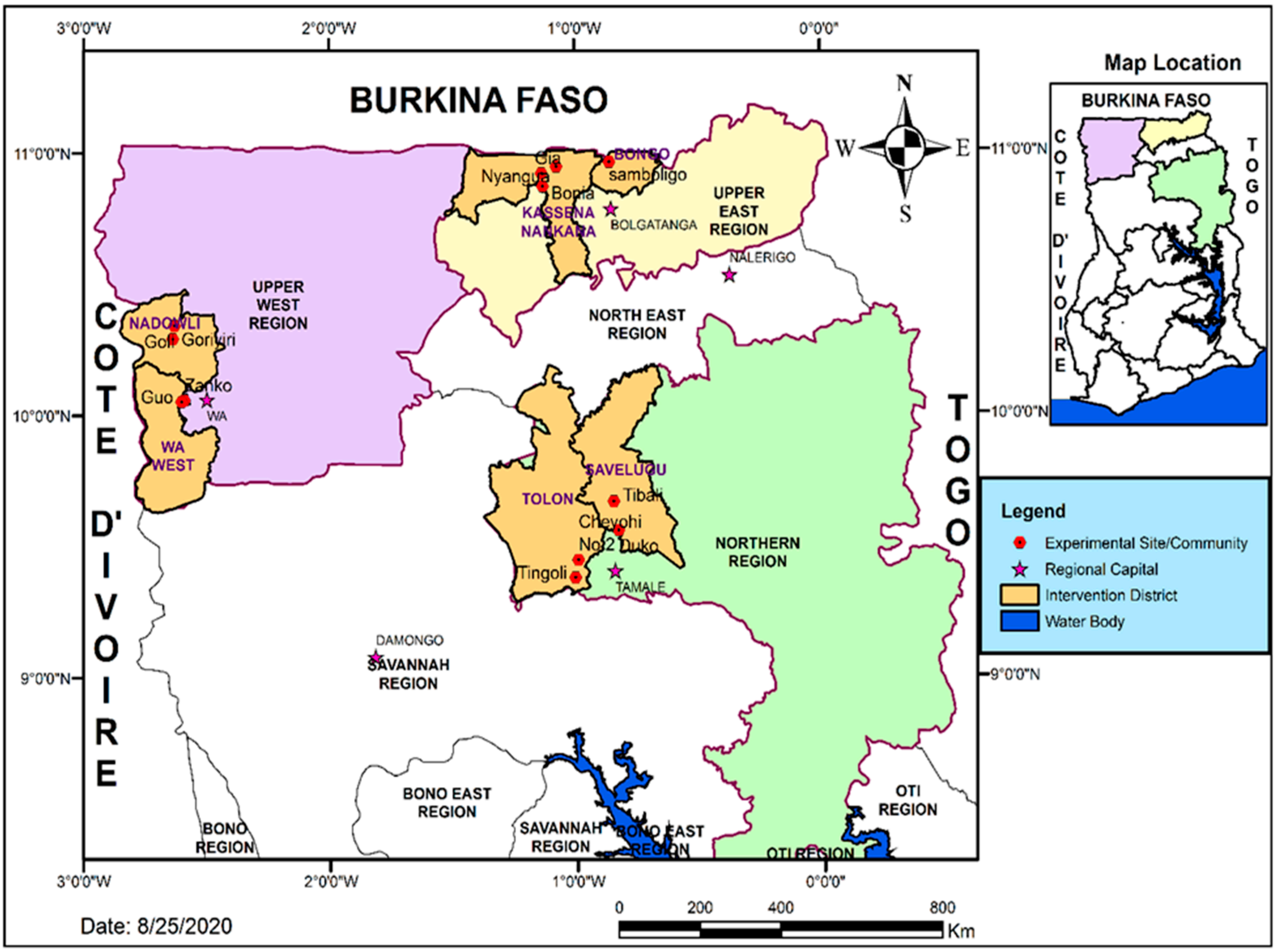

Figure 1. Map of Ghana showing experimental sites in intervention communities in northern Ghana. Source: Map projection (EPSG: 4326) and administrative layers (https://www.geoboundaries.org/ accessed on 15 June 2020).

The soil texture for the topsoil (0–20 cm) of experimental sites varied from loam to sandy loam in the Northern Region and loamy sand to sandy loam in the Upper East and the West regions [25]. The same authors also reported the nutrient composition of the topsoil (0–20 cm) from the experimental sites in the three northern regions to be generally low with a soil pH range of 5.1–7.1 (1:2.5 Soil: H_2O), total nitrogen of 0.1–1.5 g/kg, organic matter of 3.8–19.3 g/kg, available phosphorus of 1.1–10.1 mg/kg, and available potassium of 17.3–92.7 mg/kg.

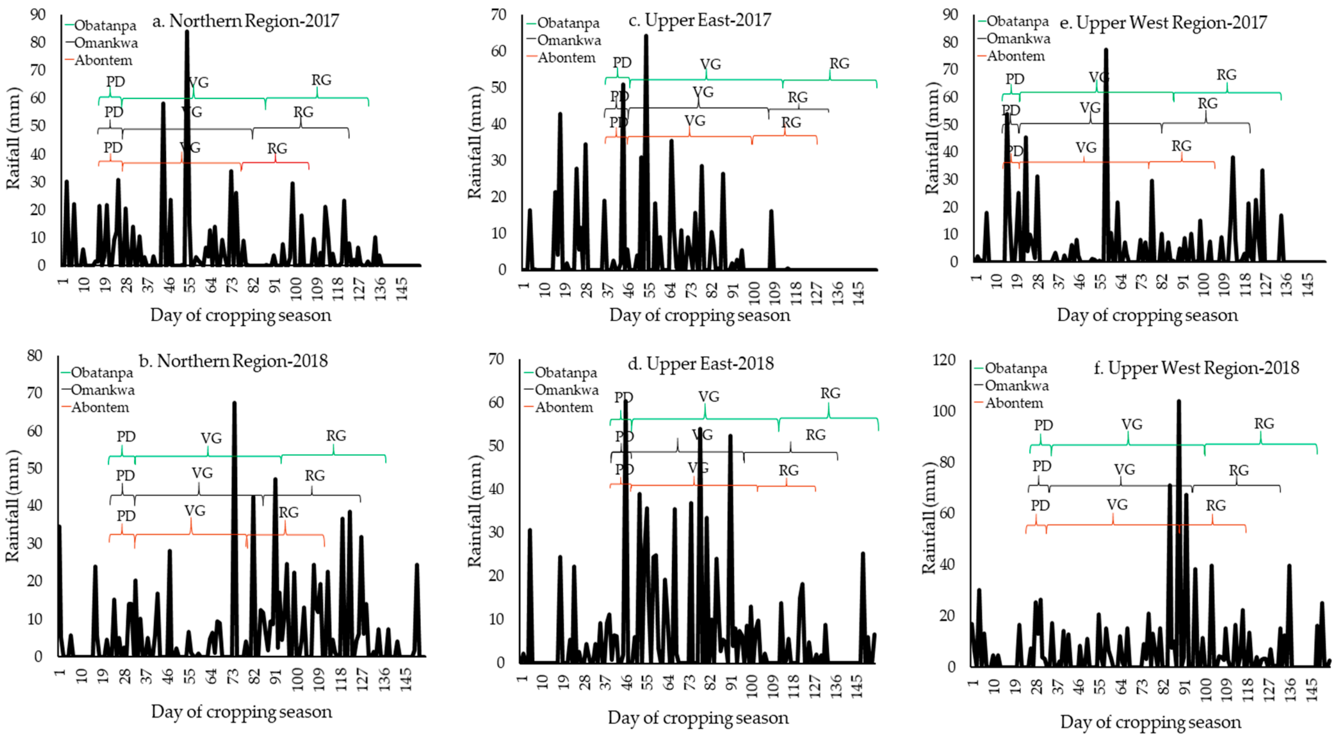

Figure 2. Daily rainfall in the Northern, Upper East, and Upper West of Ghana during the June to October of 2017 and 2018 cropping seasons. PD—planting date, VG—vegetative growth, and RG—reproductive growth.

2.2. Experimental Design

A 3 × 3 factorial treatment combination of maize maturity type and leaf stripping in a strip-plot design with four replications per region was used. The maize maturity types were extra-early: Abontem, early: Omankwa, and medium: Obatanpa. The Abontem variety had an 80-day maturity, Omankwa a 95-day maturity, and Obatanpa a 105-day maturity [5]. The authors also reported that all the maize varieties used in this study were open-pollinated and quality protein maize, and the Abontem and Omankwa varieties were drought- and Striga-tolerant in addition to earlier qualities. These maize maturity types were selected to assess how a short cropping season coupled with an erratic rainfall pattern affect growth and yield in different agro-ecological zones of northern Ghana. The maize leaf stripping included no leaf stripping, leaf stripping at 50% tasseling, and leaf stripping at 50% silking. The no leaf stripping is the conventional practice in the study area and, therefore, used as the control treatment. The leaf stripping at 50% tasseling was done by removing the lower leaves of maize plants at a height of 60 cm from the stem to ground level when half of the total plant stands in a plot had their tassel open. The leaf stripping at 50% silking was also carried out by removing the lower leaves of maize plants below the cob leaf to ground level when half of the total maize plant stands in a plot had their silk open. The above leaf stripping treatments were selected because maize leaf senescence is accelerated during reproductive growth, and the stripping of lower senescence leaves affect source–sink relations in obtaining efficient carbon and nitrogen metabolism [26,27]. The leaf stripping treatments were applied to all plants in their respective plots. The experiment was conducted in four communities of Ghana: the Northern, Upper East, and Upper West regions (Figure 1). The selected communities were part of the 25 intervention communities for Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) project across three regions of northern Ghana. Each community was used as block at the regional level where the experiment was established in a technology park for farmers to participate in, observe, and learn about the technology. The plot size for a block was 17.0 m × 15.5 m and that of a treatment was 5.0 m × 4.5 m.

2.3. Agronomic Practice

The land preparation of the experimental fields in each region was done in accordance with the common method of ploughing in each region. Thus, a tractor plough was used for the fields in Northern and Upper West regions and a bullock plough was used for fields in the Upper East Region. The maize plants were planted at a spacing of 75 cm × 40 cm at 3 seeds per hill and thinned to 2 stands per hill after 14 days to achieve plant density of 66,667 plants/ha. In the Northern Region, the maize seeds were planted 20–30 June in 2017 and 25 June–6 July in 2018. In the Upper East Region, the maize seeds were planted 4–10 July in 2017 and 4–13 July in 2018. The maize seeds were planted 17–29 June in 2017 and 28 June–12 July in 2018 in the Upper West Region. A compound NPK fertilizer (15–15–15 N-P-K) was applied at 14 days after planting to the plants at 40 kg/ha NPK. The maize plants were top dressed at 21 days after application of compound fertilizer with sulphate of ammonia at 20 kg/ha N. Hoe weeding was done twice at 14 days and 21 days after the first weeding in all the treatment plots.

2.4. Data Collection

2.4.1. Weather Data

WatchDog 2900ET (Spectrum Technologies, Aurora, IL, USA) weather gauge was installed in Tingoli community (Northern Region) and Bonia community (Upper East Region) to measure daily rainfall (mm) for each region during June–October of 2017 and 2018 cropping seasons. WatchDog runs on AA dry cell batteries; therefore, weather data gaps were filled with data from the nearest gauge stations: the Savanna Agricultural Research Institute gauge station approximately 5 km from Tingoli community in the Northern Region and the Ghana Meteorological Agency gauge station approximately 8 km from Bonia community in the Upper East Region. The Upper West data were obtained from Ghana Meteorological Agency [28].

2.4.2. Stripped Leaf Biomass and Chemical Analysis

Maize leaves were stripped at 50% tasseling and 50% silking from the respective treatment plots as described under leaf stripping treatments. The stripped maize leaves from the two middle rows (7.5 m^2) of each treatment plot were weighed to measure fresh leaf weight per plot. We sampled 0.5 kg of fresh leaf weight per plot which was oven dried at 60 °C for 48 h to determined dry matter as stripped leaf biomass. The dried samples were milled and sieved through 1 mm mesh; weighed -about 13 g per sample; and analyzed for nitrogen (kjedahl method), then the nitrogen was multiplied with 6.25 to calculate crude protein (CP) [29]. The Acid Detergent Fiber (ADF) and the Neutral Detergent Fiber (NDF) were determined with sodium sulfite and a-amylase, and exclusive of residual ash [30] using the Ankom200 (Ankom Technology, Macedon, NY, USA) fiber analyzer (Ankom ADF method 5 and NDF method 6). We determined in vitro gas production [31], and calculated in vitro organic matter digestibility (IVOMD) [32] and metabolizable energy (ME) [33]. A random sample of farmers was taken to measure the time and the quantity of stripped leaf per treatment plot.

2.4.3. Cob Dimension, Grain, and Stover Yields

Maize cobs from the two middle rows (7.5 m^2) of each treatment plot were harvested at physiological maturity and dehusked. Five random cobs per plot were selected to measure the length and the width of each cob with a vernier calliper. Grain yield was determined: the total cobs per plot were shelled, weighed as fresh grain weight per plot, sampled 0.5 kg fresh grain weight per plot, and oven dried at 60 °C to a moisture content of 13%. The maize plants, from which the cobs were harvested in the two middle rows, were cut at ground level and weighed as fresh stover weight. To determine stover yield, we sampled 0.5 kg of the fresh stover weight per plot and oven dried at 60 °C to a constant weight.

2.5. Statistical Analysis

Statistical Analysis System [34] package was used to analyze the measured stripped leaf biomass, chemical composition of stripped leaf biomass, cob dimension, grain, and stover yields with the cropping season as a replicate to determine the treatment that is stable and higher over the two seasons [35]. The model used was:

$$Y_{ijk} = \mu + B_I + M_J + (BM)_{ij} + S_K + (BS)_{ik} + (MS)_{jk} + e_{ijk} \quad (1)$$

where Y_{ijk} is an observation, μ is experimental mean, B_i is block (community) effect, M_j is maize maturity type effect, $(BM)_{ij}$ is the error effect for Maize maturity type effect, S_j is leaf stripping effect, $(BS)_{ik}$ is error for leaf stripping effect, $(MS)_{jk}$ is the interaction effect of maize maturity type and leaf stripping, and e_{ijk} is error for maize maturity type and leaf stripping effect. Treatment means with significant difference were separated using orthogonal contrast at a probability level of 0.05. Pearson correlation analysis was used to determine relationship among leaf yield, cob dimension, grain, and stover yields. A correlation coefficient (r) of ≥0.4 was considered correlated whilst r of <0.4 was considered not correlated. We also calculated the square of r and multiplied by 100 to determine the proportion of variation of Y variables attributed to X [36].

3. Results

3.1. Stripped Leaf Biomass and Chemical Composition

Maize maturity type showed significant effect on stripped leaf biomass in the Upper West Region (Table 1). The stripped leaf biomass for the Omankwa and the Obatanpa maize on the average was 61% higher ($p < 0.01$) than that of the Abontem maize (Table 1). Similarly, Obatanpa maize recorded a 33% increase ($p < 0.01$) in stripped leaf biomass relative to that of Omankwa maize in the Upper West Region (Table 1). The time taken by a female farmer to strip 1 kg of maize leaf was 8% longer than that of a male farmer (Figure 3). Leaf stripping and the maize maturity type had no significant effect on ME, IVOMD, ADF, NDF, and CP (Figure 4).

Table 1. Stripped leaf biomass as affected by maize maturity type and leaf stripping options in northern Ghana average over 2017 and 2018 cropping seasons.

	Stripped Leaf Biomass (kg/ha)			
	Northern	**Upper East**	**Upper West**	**Mean**
Maize maturity type				
Abontem (Extra-early)	731.3	910	296.4	593.1
Omankwa (Early)	820.4	990.2	408.2	689.5
Obatanpa (Medium)	1049.2	1057.3	544.0	848.7
Standard error of mean	62.38	96.66	25.82	36.51
Extra-early vs. (Early + Medium)	0.2552	0.1796	0.0001	0.0461
Early vs. Medium	0.2676	0.4668	0.0026	0.1167
Leaf stripping				
Control (No leaf stripping)				
Leaf stripping @ 50% Tasseling	752.1	944.7	416.0	656.2
Leaf stripping @ 50% Silking	981.8	1027.0	416.4	764.7
Standard error of mean	126.06	73.57	9.25	47.34
Tasseling vs. Silking	0.175	0.2879	0.9905	0.1897

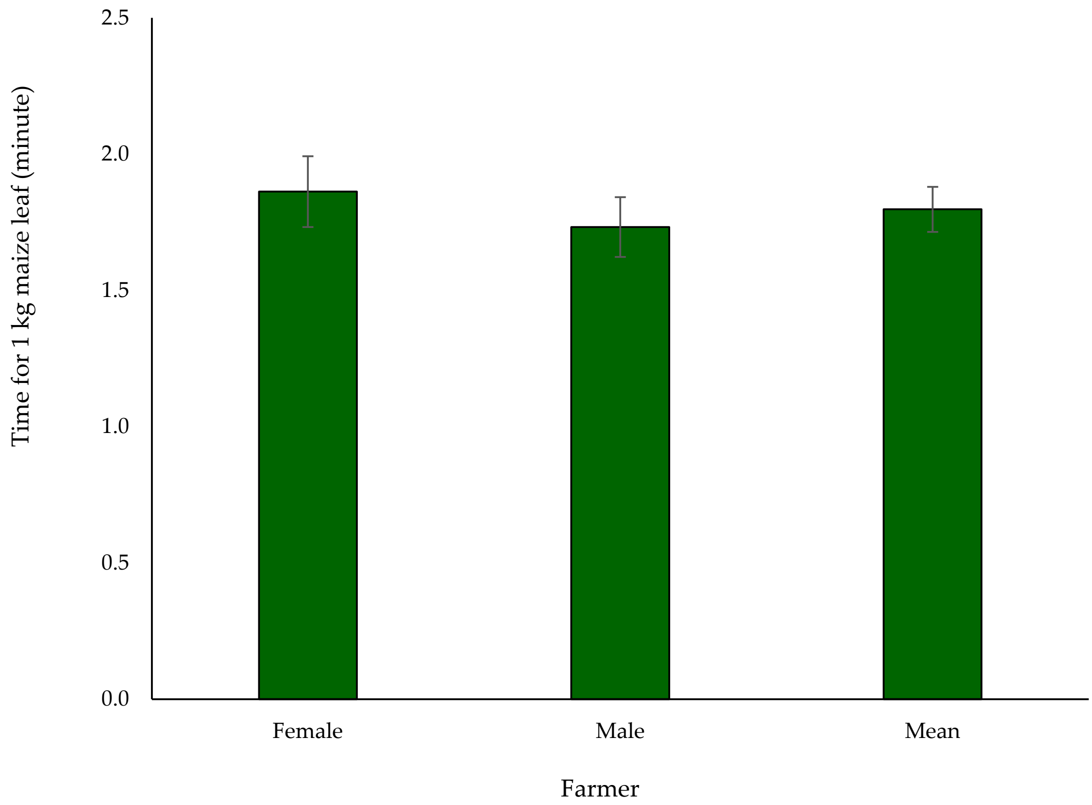

Figure 3. Time taken by farmers to harvest 1 kg of maize leaf (n = 4 gender). Bars represent standard error of mean.

3.2. Cob Dimension

Maize maturity type had significant effect on maize cob width in the Upper West Region (Table 2). The cob width of Omankwa and Obatanpa maize on the average increased ($p < 0.01$) by 13% compared with that of Abontem maize (Table 2). The cob width of Obatanpa was also 12% higher than that of Omankwa maize in the Upper West Region (Table 2).

Table 2. Maize cob dimension as affected by maize maturity type and leaf stripping in northern Ghana averaged over 2017 and 2018 cropping seasons.

	Grain Yield (kg/ha)				Stover Yield (kg/ha)			
	Northern	Upper East	Upper West	Mean	Northern	Upper East	Upper West	Mean
Maize maturity-type								
Abontem (Extra-early)	2426.1	1956.9	2296.7	2221.4	3456.6	2732.3	2483.3	2881.8
Omankwa (Early)	2655.6	1779.4	2739.4	2412.8	3497.7	2431.7	3170.0	3061.6
Obatanpa (Medium)	2463.3	1181.0	2589.4	2137.0	5215.1	3246.7	5161.1	4634.4
Standard error of mean	161.02	262.97	150.47	143.79	99.96	359.31	155.59	113.20
Extra-early vs. (Early + Medium)	0.4612	0.0039	0.0967	0.6720	0.0125	0.7018	0.0001	0.0001
Early vs. Medium	0.3583	0.0019	0.5525	0.0597	0.0001	0.0149	0.0001	0.0001
Leaf stripping								
Control (No leaf stripping)	2708.9	1591.9	2538.9	2314.7	4360.0	2907.9	3816.1	3751.2
Leaf stripping @ 50% Tasseling	2416.1	1732.5	2438.9	2215.6	4034.1	2949.1	3477.8	3508.2
Leaf stripping @ 50% Silking	2420.0	1592.9	2647.8	2240.8	3775.2	2553.7	3520.6	3318.4
Standard error of mean	137.45	149.35	152.84	61.76	237.04	192.69	169.26	88.45
Control vs. leaf stripping	0.1117	0.6509	0.9838	0.4935	0.1955	0.5753	0.3785	0.1215
Tasseling vs. Silking	0.9851	0.4409	0.4089	0.8630	0.5210	0.2239	0.9177	0.4503

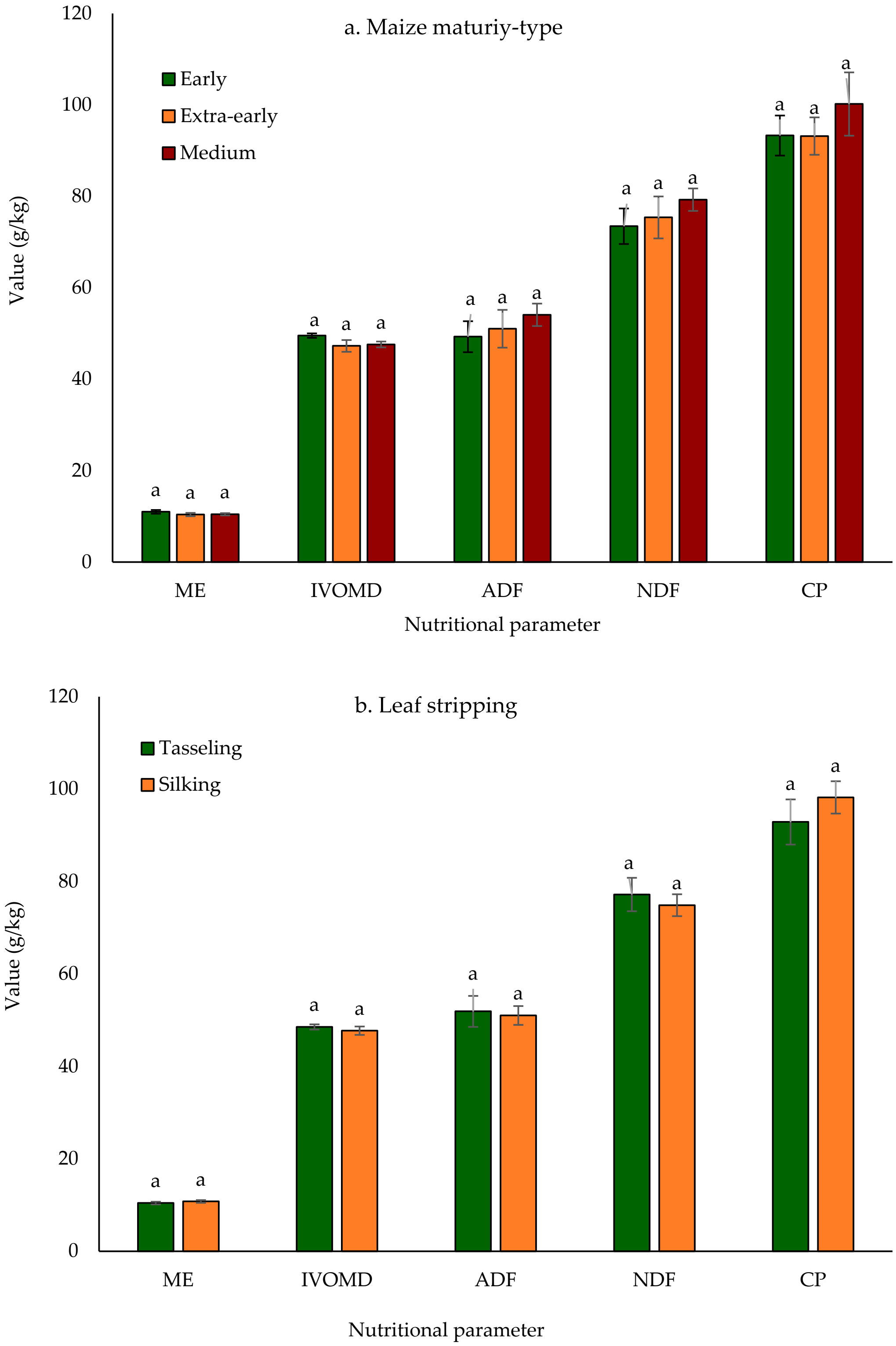

Figure 4. Maize maturity type (**a**) and leaf stripping (**b**) effect on Metabolized Energy (ME), In vitro Organic Matter Digestibility (IVOMD), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), and Crude Protein (CP) of stripped leaf biomass in northern Ghana. Error bars represent standard error of mean. Treatment means with same letters under a given nutritional parameter are not significantly different from each at a probability level of 0.05.

3.3. Grain and Stover Yields

The maize maturity type had a significant effect on maize grain in the Upper East Region (Table 3). Abotem maize recorded a 32% increase ($p < 0.01$) in maize grain yield compared with that of Omankwa maize and Obatanpa maize (Table 3). Similarly, the grain yield of Omankwa maize increased ($p < 0.01$) by 51% relative to that of the Obatanpa maize (Table 3).

Table 3. Effect of maize maturity type and leaf stripping on grain and stover yields in northern Ghana averaged over 2017 and 2018 cropping seasons.

	Cob Length (cm)				Cob Width (cm)			
	Northern	**Upper East**	**Upper West**	**Mean**	**Northern**	**Upper East**	**Upper West**	**Mean**
Maize maturity type								
Abontem (Extra-early)	14.4	11.9	12.7	13.2	7.1	3.6	3.9	5.0
Omankwa (Early)	14.9	11.3	12.9	13.2	7.0	3.8	4.1	5.1
Obatanpa (Medium)	15.5	11.3	13.6	13.7	7.3	3.7	4.6	5.4
Standard error of mean	0.42	0.35	0.30	0.12	0.30	0.09	0.07	0.10
Extra-early vs. (Early + Medium)	0.5672	0.1640	0.1950	0.6116	0.9547	0.2130	0.0001	0.5859
Early vs. Medium	0.6804	0.9397	0.1744	0.3713	0.7865	0.5670	0.0001	0.5864
Leaf stripping								
Control (No leaf stripping)	14.4	11.4	13.5	13.3	6.5	3.7	4.2	4.9
Leaf stripping @ 50% Tasseling	15.5	11.6	12.5	13.3	7.6	3.8	4.1	5.3
Leaf stripping @ 50% Silking	15.0	11.5	13.2	13.4	7.3	3.7	4.2	5.2
Standard error of mean	0.28	0.21	0.28	0.12	0.31	0.06	0.04	0.12
Control vs. leaf stripping	0.5259	0.8244	0.1376	0.8351	0.3547	0.9324	0.2510	0.4821
Tasseling vs. Silking	0.7927	0.8994	0.1808	0.8783	0.8357	0.5182	0.7159	0.8666

Maize maturity type had a significant effect on stover yield in the three regions (Table 3). The stover yield of the Omankwa and the Obatanpa maize increased ($p < 0.01$) by an average of 26% in the Northern Region and 68% in the Upper West Region (Table 3). Similarly, the stover yield of Obatanpa maize was also 49%, 34%, and 63% higher ($p < 0.05$) than that of Omankwa maize in the Northern, Upper East, and Upper West regions, respectively (Table 3). Stripping maize leaf had no significant effect on stover yield in all regions (Table 3).

3.4. Correlation among Yield, Cob Dimension and Amount of Rainfall Received during Maize Growth

Table 4 shows the correlation results of yields (leaf, grain, and stover), cob dimension, and the amount of rainfall received during the growth of the maize maturity type. Although the maize leaf yield was significantly correlated with the amount of rainfall received during vegetative and reproductive growths of the maize maturity type, it showed a positive correlation with the amount of rainfall received during vegetative growth of the maize maturity type and a negative correlation with the amount of rainfall received at the reproductive growth stage of the maize maturity type. The cob width showed an opposite correlation trend with the amount of rainfall received during growth of the maize maturity type relative to that of the maize leaf yield. The correlation trend of the grain yield with the amount of rainfall during the growth of the maize maturity type was similar to that of the cob width with rainfall amount received during the growth of the maize maturity type. The grain was also significant and positively correlated with cob dimensions and stover yield.

Table 4. Correlation among yield and yield components, amount of rainfall received during vegetive and reproductive growths of maize in northern Ghana.

	LY [1]	GY [2]	SY [3]	CL [4]	CW [5]	ARV [6]	ARR [7]
LY	1						
GY	−0.25 ns	1					
SY	0.28 ns	0.45 **	1				
CL	0.03 ns	0.54 **	0.45 **	1			
CW	0.25 ns	0.41 **	0.44 **	0.88 **	1		
ARV	0.52 **	−0.75 **	−0.25 ns	−0.42 **	−0.35 *	1	
ARR	−0.41 **	0.76 **	0.42 **	0.54 **	0.44 **	−0.82 **	1

[1] Leaf yield, [2] Grain yield, [3] Stover yield, [4] Cob length, [5] Cob width, [6] Amount of rainfall received at vegetative growth of maize, [7] Amount of rainfall received at reproductive growth of maize, ns $p > 0.05$, * $p < 0.05$ and ** $p < 0.01$.

4. Discussion

4.1. Stripped Leaf Biomass and Chemical Composition

The significant increase in stripped leaf biomass among the maize maturity types observed in the Upper West Region could be attributed to differences in the days to physiological maturity which allowed adequate time for development and partition of dry matter into yield. In line with our finding, another study reported an increase in crop yield with increasing days to physiological maturity [37]. The stripped leaf biomass showed a positive correlation with the amount of rainfall received during the vegetative growth of the maize maturity type, which indicates that an increase in the amount of rainfall received during vegetative growth of the maize maturity type corresponds to an increase in stripped leaf biomass. This relationship also shows that approximately 27% of the total variation in stripped leaf biomass could be explained by the difference in the amount of rainfall received during the vegetative growth of maize maturity type (Figure 2).

Given that the size of small ruminant herd per household in northern Ghana is 0.9 TLU, the average live body weight of adult Djallonké sheep and goats is about 25.5 kg and the average daily feed intake of a small ruminant is 3.2% of the body weight [6,38]. Hence, the daily feed requirement for Djallonké sheep and goat will be 7.2 kg dry matter per small ruminant. The average stripped leaf biomass across the three regions for Obatanpa maize was 848.7 kg/ha and using it as the sole diet for feeding small ruminants during the cropping season will provide feed for 118 days for the small ruminant herd size per household in northern Ghana. Similarly, considering an average stripped leaf biomass of 764.7 kg/ha for leaf stripping at 50% silking across the three regions and using it as a sole diet for feeding the small ruminant herd size per household in northern Ghana during the cropping season will provide feed for 106 days [6,38]. The number of feeding days for the small ruminant herd size per household from the maize leaf stripping shows the potential of the technology in providing feed to bridge the feed gap during the cropping season. Komarek et al. [18] reported an increase in daily liveweight gain of weaner sheep fed with maize leaf stripping at 50% silking compared with the daily liveweight gain of weaner sheep without maize leaf stripping feed in northern Ghana.

Given that female and male farmers take 1.9 and 1.7 min, respectively, to strip 1 kg of maize leaf (Figure 3), then to strip the daily feed requirement for small ruminants per household size (7.2 kg/0.9 TLU), it will take a female farmer 13 min and a male farmer 12 min. Whereas stripping the same quantity of maize leaf per day for 106 days will take a female farmer 23 h and a male farmer 21 h of extra labor time to harvest feed for small ruminants. This shows that stripping maize leaf to feed small ruminants in smallholder maize–livestock farming systems increases labor time for maize production. The increase in labor time for maize production as a result of leaf stripping can be managed by smallholder maize–livestock farmers considering the time involved on a daily basis and the advantages of the technology, such as collection of manure, live body weight maintenance of livestock, and prevention of animal theft. In line with our results, another study reported a 6%

increase in labor time for maize production with leaf stripping relative to maize production without leaf stripping on a subsistence basis [18].

The CP content of the stripped leaf biomass from the maize maturity type and leaf stripping were in line with the CP values of green maize forage reported by other studies [17,39]. The CP content of a feed is one of the key nutritional parameters in determining the quality of the feed. According to NRC [40], the minimum CP content level of feed required for body weight maintenance of ruminants is between 53 to 70 g/kg. Comparing the CP content recorded by the maize leaf stripping in this study with that of feed requirement for body maintenance of ruminants shows the prospects of using maize leaf stripping as a sole diet or supplementary diet for feeding ruminants during feed scarcity periods, especially in the cropping season. Mineral and protein supplements, such as cotton seed cake and haulms of leguminous crops (groundnut, cowpea, pigeon pea), will be required in addition to maize leaf stripping to increase daily growth of livestock beyond body maintenance for meat production during the cropping season in smallholder maize–livestock farming systems.

4.2. Cob Dimension

The significant effect of maize maturity type on cob width observed in the Upper West Region could be due to differences in the genetic traits of the maize varieties, an environmental influence on the performance of the traits, or a combination of both. The variation could also be attributed to the difference in days to maturity of the maize varieties as the medium maize maturity type tend to have more growth days than that of the extra-early maturity type for accumulation and partition of dry matter into cob growth. The positive and significant correlation between cob width and the amount of rainfall received during the reproductive growth of the maize maturity type shows that about 19% of the total variation in cob width could be explained by the differences in the amount of rainfall received by maize maturity type at reproductive growth. In line with our results, another study reported significant differences in the maize cob width of different maturity periods [41].

4.3. Grain and Stover Yields

The statistical differences observed among the maize maturity types on grain and stover yields could be explained by the difference in genetic traits, environmental factors (rainfall pattern and soil fertility), a combination of genetic traits and environmental factors, as well as days to physiological maturity. The differences in the amount of rainfall received during the growth of the maize, especially at the reproductive growth of the maize maturity types, could also explain the variation in grain and stover yields (Figure 2). These relationships show that about 58% of the variation in grain yield could be explained by differences in the amount of rainfall received by maize maturity type during the vegetative and reproductive growths. Similarly, about 18% of the variation in stover yield of the maize maturity type could be attributed to differences in the amount of rainfall received by the maize maturity type during reproductive growth. In consonance with our results, other studies have reported higher grain and stover yields for the early to medium maize maturity type relative to that of the extra-early maturity type in the Northern and the Upper West regions and vice versa in the Upper East Region of Ghana [42,43]. The average grain yield recorded from this study compared with the potential yield was low [9], but it was 44% higher than the average grain yield of maize for the three regions [10]. The low grain and stover yields observed from the study could be explained by the erratic rainfall pattern (Figure 2) and the poor fertility status of soils in the regions [25], as they affect the genetic potential of the maize.

The grain and stover yields showed no response to leaf stripping and these results support the reports from other studies on the effect of leaf stripping on maize grain and stover yields [17,18,22]. The above reports on the effect of leaf stripping on grain and stover yields shows the potential of the technology in addressing the challenge of feed scarcity during the cropping season for maize–livestock farmers. However, the results of this study contrast the findings that leaf stripping increased the grain yield in maize and wheat relative to the control treatment [24,44] and a reduction in the grain yield of leaf stripping treatment compared with the control treatment [18–20].

5. Conclusions

Maize maturity type showed a significant response to stripped leaf biomass, cob width, grain, and stover yields. Relative to the other maize maturity types in the Northern and the Upper West regions, Obatanpa maize significantly increased stripped leaf biomass by 33–61%, cob width by 12–13%, and stover yield by 26–68%. The grain yield of Abontem maize was 32% higher ($p < 0.01$) than that of Omankwa and Obatanpa maize in the Upper East Region. However, in the Northern and the Upper West regions, the grain yield of the maize maturity types was not statistically different. The maize maturity type and leaf stripping had no significant effect on the ME, IVOMD, ADF, NDF, and CP content of maize leaf yield. The CP content of the stripped leaf biomass for maize maturity types at tasseling and silking ranged between 93 to 100 g/kg which meets the minimum CP requirement of a quality feed for body weight maintenance of ruminants. The results suggest: (i) smallholder maize–livestock farmers in the dry savanna could plant extra-early to early maturity maize types, whilst those in the wet savanna could cultivate early to medium maturity types as a mitigation measure against erratic rainfall patterns for better grain yields; and (ii) they could strip maize lower leaves at either tasseling or silking to feed to their livestock without significant effect on maize grain yield during scarce feed periods in the cropping season in northern Ghana and similar agro-ecological zones in West Africa. Further studies on testing the potential of the leaf stripping technology in the context of large-scale maize–livestock farming systems is warranted as this may show different technological dynamics.

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