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Estimating Forage Yield and Nutritive Value of Maize-Legume Intercropping Systems in Paddy Fields During Summer

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Abstract The aim of the present study was to evaluate the forage yield and nutritive value of maize–legume intercropping systems in non-cultivating paddy fields. The fields were sprayed with 210 kg ha^{-1} of nitrogen composite fertilizer [NPK (21-17-17)] before seeding. Maize cv. '32P75' was simultaneously cultivated with two cultivars of soybean ('Chookdu 1' and 'Chookdu 2') and lablab (cv. 'Rongai') from 2018 to 2019 at the National Institute of Animal Science, Cheonan, Republic of Korea. After seeding, pendimethalin herbicide was sprayed on the fields, and soil and plant parameters, including soil chemical composition, plant characteristics, productivity, and feed values, were estimated. The soil in the intercropping treatments had higher nitrogen content and P_2O_5 utilization rate than the maize monoculture. The productivity [dry matter yield (DMY) and total digestible nutrients] of the fields under the intercropping and monoculture treatments during 2018 were not significantly different. However, the field productivity of the intercropping treatments during 2019 were remarkably higher than that of the maize monoculture; the productivity of M × S1 field was the highest ($p < 0.05$) among all the treatments, with 9.5% of the total DMY resulting from the intercropped soybean cultivar. Moreover, the feed value of intercropped legumes was higher than the monocrop maize stalks; the crude protein yields of M × S1 and M × S2 fields were significantly higher than that of the maize monocrop during 2019 ($p < 0.05$). In addition, the feed value, except crude protein content, of the treatment with intercropped lablab was higher than that with the maize monocrop. Thus, these findings provide an insight into the role of alternative cropping in improving the forage yield of paddy fields.

Keywords: *forage yield, intercropping, legume, maize, feed value*

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1. Introduction

The per capita rice consumption in the Republic of Korea has decreased from 132 kg in the 1980s to 93 kg in the 2000s and 59 kg in 2017; this subsequently increased rice stocks to 1,702 t and decreased the area under rice cultivation to 750,000 ha in 2017 [1]. Consequently, rice production and consumption are expected to decrease in the future, rendering numerous paddy fields unused. Therefore, it is necessary to develop cropping methods using alternative crops that can be cultivated in the abandoned paddy fields.

Paddy fields in the Republic of Korea are acidic and have poor drainage systems and low organic content. Intercropping is more beneficial than monocultures as it reduces the competition between crops for resources. Furthermore, cultivating cereals with legumes not only improves forage yield through efficient legume–rhizobial symbiosis between two intercropped species [2] but also increases protein content and other seed quality parameters [3,4]. Intercropping also improves soil fertility through nitrogen fixation by the leguminous species [4,5,6,7]; for example, intercropping 70% rye and 30% common vetch [8] with grasses and legumes improved soil quality and enhanced growth and development in grass.

The ability of legumes to fix atmospheric nitrogen varies between species; soybean can fix 49–450 kg ha^{-1}, alfalfa 100–300 kg ha^{-1}, and clover 100–150 kg ha^{-1} nitrogen [9]. Moreover, crimson clover (*Trifolium incarnatum* L.) fixes 43 kg ha^{-1} of nitrogen, which is essential for maize growth and development [10]. However, humidity prevents the successful cultivation of legumes in paddy fields, as many leguminous species are vulnerable to humidity. High soil moisture content impedes plant aeration, thereby affecting their survival, especially during the summer and rainy seasons in the Republic of Korea. As water would be distributed between legumes and the intercropped plants, intercropping can alleviate the effects of wet soil conditions in paddy fields on legumes during the rainy season, especially when legumes are cultivated with maize (*Zea mays* L.), a crop that requires large quantities of water than other grasses. For example, maize–soybean intercropping increased water use efficiency compared to soybean monocultures.

Previous studies suggest that mutual shading under intercropped plants regulates microclimatic conditions by reducing soil water loss and improving transpiration [11]. Thus, land equivalent ratio [12], seeding ratio, and intercropping pattern positively affect crop productivity and make intercropping economically advantageous [13]. Therefore, the present study aimed to determine the optimal maize–legume intercropping system in a paddy field by estimating the growth characteristics, productivity, and feed value of the crops in the intercropping systems with different legume species.

2. Materials and Methods

2.1. Study Sites and Design

The intercropping experiments were conducted at the National Institute of Animal Science (Rural Development Administration), Cheonan, Republic of Korea (36° 55′ 54.1″ N, 127° 06′ 21.9″ E) from April 2018 to August 2019. Previous studies reported that when cereals were grown with legumes, crop yield and other quality parameters were increased [4]. Therefore, in this study, we intercropped the maize cultivar ‘32P75’ with the legume species soybean [*Glycine max* (L.) Merr. cv. ‘Chookdu 1’ and ‘Chookdu 2’] and lablab [*Lablab purpureus* (L.) Sweet cv. ‘Rongai’].

Maize and each legume species were sown in two equally spaced 0.75 m-long rows (each experimental treatment), resulting in a total of four rows in each experimental plot. The side rows on either side of the plots were considered for border effect only. The distance between the maize seeds within each row was 20 cm and that between the legume seeds was 20 cm. Thus, the distance between a maize and a legume seed was 10 cm. All the treatments were conducted in triplicates using a randomized block design. The first and second experimental periods extended from April 30, 2018 to August 11, 2018 and May 15, 2019 to August 30, 2019, respectively.

2.2. Field Preparation and Herbicide Selection

A total of 210 kg ha^{-1} of NPK (21-17-17) composite fertilizer and pendimethalin herbicide (Stomp, Korea) were applied to the plots before and after seeding, respectively. Pendimethalin was selected over alachlor (Lasso) and simazine, the commonly used herbicides on maize farms in the Republic of Korea, because they negatively affect legumes. Moreover, the weed controlling ability of pendimethalin is better than other herbicides, which contributes to higher yields of the main crops [14].

2.3. Climate at the Study Site

The temperature and precipitation data of the study site for a 10-year-period are given in Figure 1 and Figure 2. During 2018, the average monthly temperatures at the study site were higher than those during the 2008–2017 period, whereas the monthly precipitation was relatively low, especially the period between July and August 2018, which coincides with the grain-filling period. In contrast, the average monthly temperatures during 2019 were lower than those during the 2018–2019 period, and the monthly precipitation was noticeably lower than the previous decade.

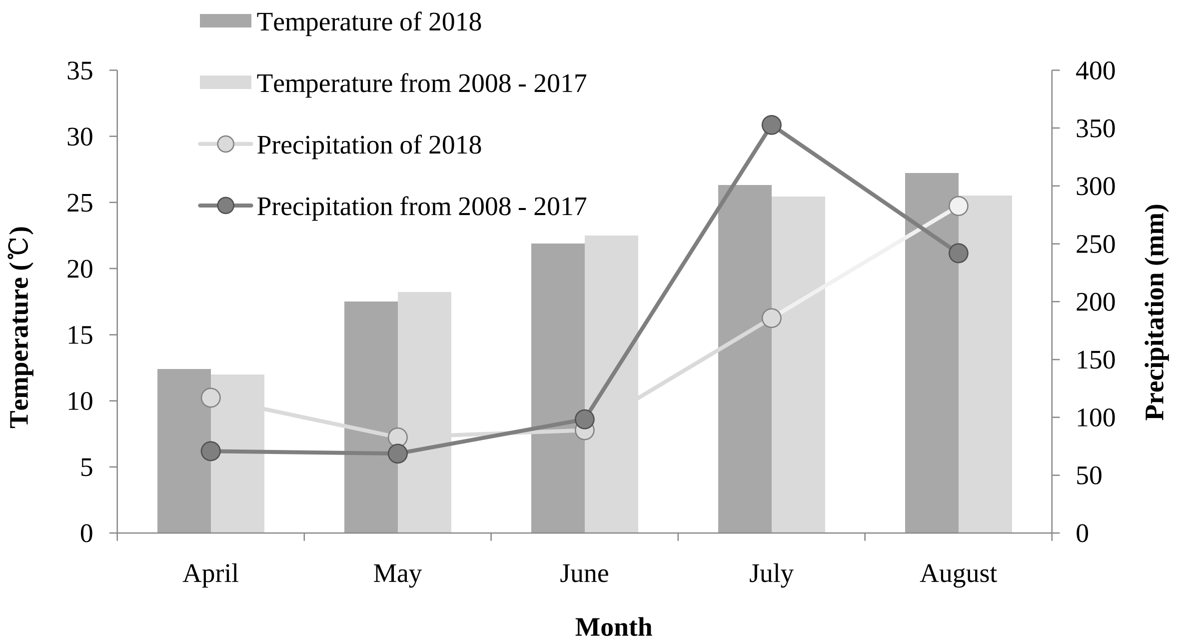

Figure 1. Average monthly temperature (°C) and monthly precipitation (mm) at the study site during 2018 [33]

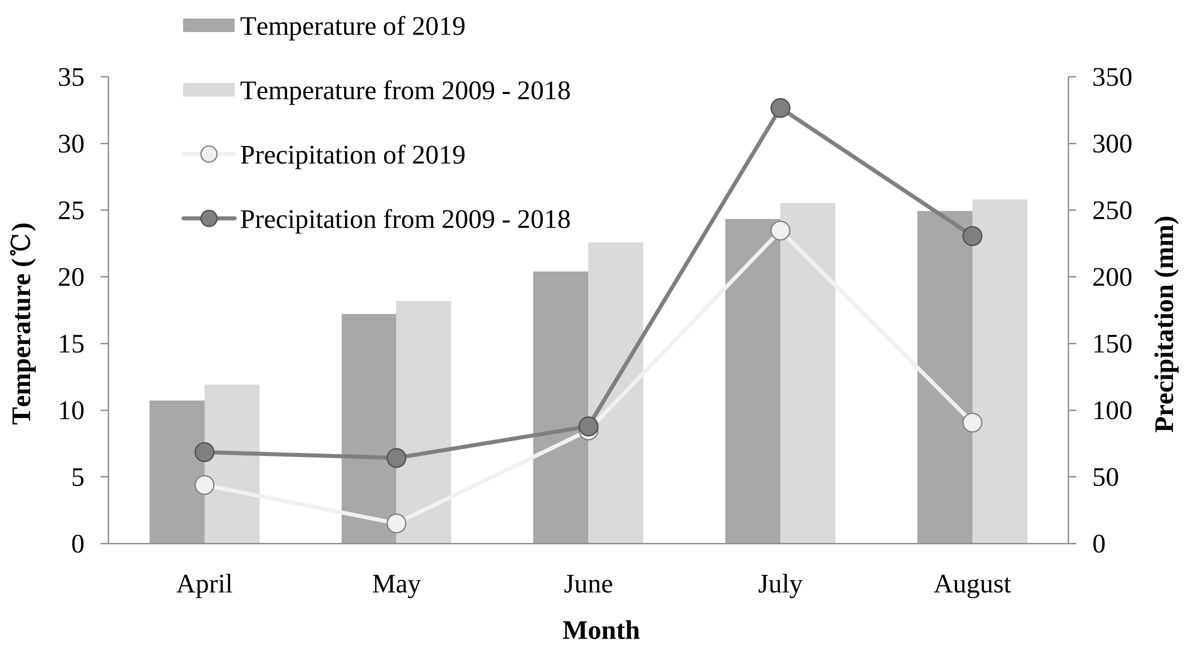

Figure 2. Average monthly temperature (°C) and monthly precipitation (mm) at the study site during 2019 [33]

2.4. Measurements of Soil Chemical Properties

Soil samples were collected from a depth of 20 cm from three different locations in each treatment replicate of the study site. The collected soil samples were sieved through a 2-mm mesh and then used to determine soil pH, nitrogen content, electrical conductivity (EC), available P_2O_5, and exchangeable cations, according to the protocol of National Institute of Agricultural Science and Technology (NIAST) [15]. Soil pH and EC were measured using a pH meter (Orion 3-Star, Thermo Scientific, USA) and EC meter (Orion 3-Star, Thermo Scientific, USA), respectively. Total soil nitrogen content and available P_2O_5 were measured using the Kjeldahl (Kjeldahl Auto Sampler System 1035 analyzer) and molybdenum blue (UV-spectrometer; UV 1800, Shimadzu, Japan) methods, respectively. The exchangeable cations were measured using inductively coupled plasma-optical emission spectroscopy (ICP-OES; iCAP 7000 Series ICP-OES, Thermo Scientific, Cambridge, UK) by mixing 5 g of soil sample to 50 mL of 1 N ammonium acetate (pH 7.0) solution for 30 min.

2.5. Measurements of Crop Yield and Nutritive Value

The productivity (kg ha^{-1}) of each intercropping treatment was calculated using the weight of the plants harvested from the two central rows of each plot. To estimate the dry matter (DM, %), two plants were collected from each replicate and their fresh weights were measured. These samples were then oven-dried at 70°C for 72 h and weighed again. The dry matter yield (DMY; kg ha^{-1}) was calculated using the fresh weight and DM. Neutral detergent fibers (NDF) and acid detergent fibers (ADF) were estimated following the procedure described in [16], and crude protein (CP, %) content was measured using the method described in [17]. The relative feed value (RFV) and total digestible nutrient (TDN) value were calculated as follows [18]:

$$\begin{aligned}&\textit{Maize TDN yield}\\&=\begin{bmatrix}(\textit{DM yield of maize stalk}\times 0.582)\\+(\textit{DM yield of maize ear}\times 0.85)\end{bmatrix}\end{aligned} \quad (1)$$

$$\begin{aligned}&\textit{Legume TDN yield}\\&=\left[\textit{DM yield of legume}\times\textit{legume TDN }(\%)\right]\end{aligned} \quad (2)$$

$$\textit{Legume TDN }(\%)=[88.9-(0.79\times \textit{ADF }\%)] \quad (3)$$

$$\textit{RFV}=\left[(\textit{DDM}\times\textit{DMI})/1.29\right] \quad (4)$$

$$\textit{Digestible DM }(\textit{DDM})=\left[88.9-(0.779\times\textit{ADF}\%)\right] \quad (5)$$

$$\begin{aligned}&\textit{DM Intake }(\textit{DMI};\%\textit{ of body weight})\\&=\left[120/(\textit{NDF }\%)\right]\end{aligned} \quad (6)$$

2.6. Data Analyses

Data was analyzed using the statistical software package SPSS 12.0 (SPSS Inc., Chicago, IL, USA). The continuous variables were presented as mean ± standard error, and differences were verified using Duncan's multiple range test.

3. Results and Discussion

Previous studies reported that the paddy fields in the Republic of Korea were acidic [19,20,21,22]. However, in this study, the pH of the soil of the paddy fields were 7.1 and 6.6 during 2018 and 2019, respectively, both of which are optimal for maize and legume growth. Table 1 lists the chemical properties of the soil at the study site. We observed that soil pH was higher in the intercropping treatments than that in the maize monocrop. Additionally, EC revealed an irregular pattern during both 2018 and 2019, but it was less affected in the intercropping treatments. The average nitrogen content before cultivation was 0.145 % during the study period (2018-2019). Furthermore, the total soil nitrogen content was higher in the intercropping treatments than in the maize monoculture. This can be attributed to the nitrogen-fixing ability of the legumes, as they have the ability to fix atmospheric nitrogen needed for normal growth and development of the maize crop and increase crop yield by facilitating root growth of the intercropped legume. In contrast, maize had a lower P_2O_5 utilization rate than both the legumes, resulting in a higher soil P_2O_5 content in the maize monoculture than in the intercropping treatments because the composite chemical fertilizer was applied before sowing. This was also attributed to the potential of intercropping to increase the utilization efficiency of nutrients in the soil. Similar results were observed for soil potassium content. However, soil calcium and magnesium contents were relatively less affected by the cropping treatments used in this study.

The characteristics of plants used in the cropping treatments are shown in Table 2. Most of the cereal–legume intercropping systems are used for nitrogen fixation in the soil, making the nutrient readily available to the crop plant [23,24]. However, in this study, maize plant and ear heights were not significantly different between the cropping systems during the study period, whereas, the legume height was the highest in the M × L intercropping treatment during 2019 ($p < 0.05$). Moreover, we selected legumes with improved climbing habit for the intercropping treatments, because maize acts as a support for the climbing legumes.

In 2019, maize stalk, ear, and total DM were not significantly different between the maize monoculture and the intercropping treatments. This was attributed to torrential rains during the summer of 2018, rendering the soil unfit and thus an unstable maize productivity of the paddy field, which was affected by several variables. Therefore, further investigation on intercropping two crops with different characteristics are necessary to ensure stable feed production.

One of the key determinants of a productive paddy field for growing feed crops is the field drainage conditions [25]; previous studies suggest that increasing drainage depth increased the total, fresh, DM, and TDN yields of the maize crop [26]. However, maize DM yield was not significantly different between 2019 and 2018 (Table 3). Nonetheless, there was a significant difference in the total DM yield between 2018 and 2019, among which M × S1 (13,269 kg ha^{-1}) and M × LL (13,020 kg ha^{-1}) had the highest total DM yields during 2019 ($p < 0.05$) (Table 3). Previous studies have shown that the nitrogen-fixing ability of legumes is better in soils with low nitrogen content [27,28], and it varies from season to season [29,30]. In this study, nitrogen fixation was irregular because of sufficient nitrogen in the soil, which was added before sowing, resulting in small differences in maize productivity.

Table 1. Chemical properties of the paddy field soil collected from various treatment sites during 2018 and 2019

Years	Treatments	pH	N (%)	Available P_2O_5 (mg kg^{-1})	EC (ds m^{-1})	OM (g kg^{-1})	Exchangeable cations (cmol kg^{-1})		
							Ca	K	Mg
2018	BC	7.10	0.138	31.00	63.56	4.51	0.542	0.247	0.198
	MM	7.71	0.096	42.65	157	6.83	1.854	0.518	0.183
	M × S1	8.01	0.224	49.70	100	9.86	1.665	0.253	0.145
	M × S2	7.94	0.167	34.95	94.5	10.58	1.451	0.243	0.145
	M × L	8.09	0.117	28.05	78.6	10.71	1.910	0.301	0.217
2019	BC	6.64	0.152	31.36	31.00	5.87	1.803	0.085	0.525
	MM	6.41	0.106	65.26	42.65	7.59	1.668	0.149	0.496
	M × S1	8.09	0.158	54.67	34.95	6.05	1.927	0.124	0.473
	M × S2	7.94	0.128	54.47	28.05	8.59	1.777	0.162	0.488
	M × L	8.09	0.132	26.66	49.70	11.62	1.777	0.079	0.635

$^{a\text{-}b}$ chemical properties within a row without a common superscript letter are significantly different ($p < 0.05$). ^{ns} indicates not significantly different. SEM: standard error of the mean; BC: before cultivation; MM: maize monocrop; M × S1: maize and soybean (‘Chookdu 1’) intercropping; M × S2: maize and soybean (‘Chookdu 2’) intercropping; M × L: maize and lablab (‘Rongai’) intercropping; EC: electrical conductivity; OM: organic matter.

Table 2. Characteristics of plants used in the different cropping treatments in the paddy fields from 2018 to 2019 during the summer season

Years	Treatments	Maize (cm)		Legume height (cm)
		Plant height	Ear height	
2018	MM	234^{ns}	106^{ns}	-
	M × S1	253	110	110^{ns}
	M × S2	250	115	88.1
	M × L	237	104	104
	SEM	19.1	8.17	8.55
2019	MM	257^{ns}	112^{ns}	-
	M × S1	255	112	102^{b}
	M × S2	257	107	115^{b}
	M × L	252	105	138^{a}
	SEM	2.24	1.64	3.90

$^{a\text{-}b}$ means within a row without a common superscript letter are significantly different ($p < 0.05$). ^{ns} means not significantly different. SEM: standard error of the mean; MM: maize monocrop; M × S1: maize and soybean (‘Chookdu 1’) intercropping; M × S2: maize and soybean (‘Chookdu 2’) intercropping; M × L: maize and lablab (‘Rongai’) intercropping.

Table 3. Effects of different cropping treatments on the dry matter yield of maize and soybean in the paddy fields during the summer season

Years	Treatments	Maize (kg ha^{-1})		Soybean (kg ha^{-1})	Total (kg ha^{-1})	Maize (%)		Soybean (%)
		Stalk	Ear			Stalk	Ear	
2018	MM	8,639^{ns}	4,349^{ns}	-	12,988^{ns}	66.6	33.4	-
	M × S1	8,821	4,172	1,783^{a}	14,643	59.9	27.8	12.3
	M × S2	8,602	4,804	1,240^{b}	14,777	57.7	32.7	8.7
	M × L	9,093	5,188	1,131^{b}	15,412	59.1	33.5	7.4
	SEM	604	509	58.6		1,059	0.91	1.01
2019	MM	6,839^{ns}	3,639^{ns}	-	10,487^{b}	63.4	36.6	-
	M × S1	7,646	4,384	1,238^{ns}	13,269^{a}	57.5	33.1	9.5
	M × S2	7,094	4,261	1,281	12,637^{ab}	55.9	34.2	9.9
	M × L	7,702	4,371	948	13,020^{a}	59.1	33.7	7.3
	SEM	459	161	109	1,059	1.35	1.54	0.53

$^{a\text{-}b}$ means within a row without a common superscript letter are significantly different ($p < 0.05$). ^{ns} means not significantly different. SEM: standard error of the mean; MM: maize monocrop; M × S1: maize and soybean ('Chookdu 1') intercropping; M × S2: maize and soybean ('Chookdu 2') intercropping; M × L: maize and lablab ('Rongai') intercropping.

Table 4. Effects of different cropping treatments on the feed value of maize in the paddy fields during the summer season

Years	Treatments	NDF (%)	ADF (%)	CP (%)	CP ear (%)	DDM (%)	DMI (%)	RFV
2018	MM	68.9^{b}	41.9^{b}	3.80^{b}	8.38^{ab}	56.3^{b}	1.74^{b}	76.0^{b}
	M × S1	73.7^{c}	44.0^{c}	4.39^{a}	8.20^{ab}	54.6^{c}	1.63^{c}	69.0^{c}
	M × S2	71.9^{c}	42.0^{b}	3.93^{b}	8.77^{a}	56.2^{b}	1.67^{c}	72.7^{bc}
	M × L	65.9^{a}	37.5^{a}	3.88^{b}	7.93^{b}	59.7^{a}	1.82^{a}	84.3^{a}
	SEM	0.49	0.41	0.09	0.16	0.32	0.01	0.94
2019	MM	61.4^{ns}	33.4^{ns}	5.44^{b}	9.02^{b}	62.9^{ns}	2.00^{ns}	95.5^{ns}
	M × S1	64.3	33.4	5.18^{b}	8.80^{b}	62.9	1.88	91.4
	M × S2	62.1	32.1	7.00^{a}	9.56^{a}	64.0	1.93	95.9
	M × L	62.7	32.0	5.41^{b}	8.80^{b}	64.0	1.91	94.8
	SEM	0.80	1.46	0.32	0.10	0.62	0.05	2.91

$^{a\text{-}c}$ means that the effects within a row without a common superscript letter are significantly different ($p < 0.05$). ^{ns} means not significantly different. SEM: standard error of the mean; NDF: neutral detergent fiber; ADF: acid detergent fiber; CP: crude protein; DDM: digestible dry matter; DMI: dry matter intake; RFV: relative feed value: MM: monocropping maize; M × S1: maize and soybean ('Chookdu 1') intercropping; M × S: maize and soybean ('Chookdu 2') intercropping; M × L: maize and lablab ('Rongai') intercropping.

Table 4 shows the fiber content of the maize stalk and CP content of the maize ear. In 2018, the NDF and ADF values of maize stalks were different among all the cropping treatments despite using the same variety of maize seedlings. As DDM, DMI, and RFV were calculated using NDF and ADF values, they exhibited the same trend as NDF and ADF values. In contrast, there was no significant difference between the NDF and ADF values in 2019. Moreover, the feed value of maize stalks in 2019 was higher than that of 2018, but the reason for this difference could not be determined as the feed values were affected by high temperatures and precipitation during 2018.

Furthermore, the CP content of maize ear was the highest in M × S2 (9.17 %) and the lowest in M × LL (8.36 %) intercropping treatments in both 2018 and 2019 ($p < 0.05$). The CP content varies depending upon the soil conditions such as the drainage system. The CP content in maize at a drainage depth of 50 cm was higher than than that at 0 cm drainage depth [26]. As the paddy field used in this study had never been used for crop production other than that of rice, there were differences in drainage depth. Moreover, CP content is strongly associated with the harvesting time, for example, soybean plants harvested at the R6 growth stage contain 15-20 % protein [31].

The fiber content, CP, and IVDMD of legumes are shown in Table 5. In 2019, the intercropped 'Chookdu 2' had the highest CP content (15.2 %) among the cropping treatments. In the intercropping treatments, legumes were simultaneously harvested with maize. Therefore, the legume yields were not significantly increased, as they were harvested prematurely, and most of the legumes had a CP content of < 15 %, with the lowest content in M × L intercropping treatment (two-year average of approximately 8.4 %; $p < 0.05$). The legume NDF and DMI values were higher than those of the maize stalks in both 2018 and 2019. The M × L intercropping treatment had the lowest NDF content, the highest two-year average RFV (approximately 122.5), and the highest IVDMD (> 72%) among the intercropped legumes ($p < 0.05$). In addition, the legume ADF values were not as high as those of maize; however, the legume RFV values were higher those of maize stalks in all treatments, except for the intercropped 'Chookdu 2' during 2018.

Grass or roughage can be classified into the following grades: supreme ADF (31% or less ADF), first-grade ADF (31–35% ADF), second-grade ADF (36–40% ADF), supreme NDF (less than 40% NDF), first-grade NDF (less than first), and second-grade NDF (47–53% NDF) [18]. The feed is considered inferior if the feed value exceeds this range. In this study, the feed values of intercropped 'Chookdu 1' and lablab were second- and first-grade, respectively, making them suitable for use as animal feed such as silage.

The DM CP yields of maize and soybean, estimated using the DM yield and CP content, are shown in Table 6. The CP yield of maize was not significantly different for monocropping and intercropping treatments during 2018;

however, non-significant differences were observed, with the highest CP yield in the M × S1 (1,000 kg ha^{-1}) intercropping treatment. However, the DM CP yield of the treatment with 'Chookdu 1' (244 kg ha^{-1}), was lower than that of maize monocrop (280 kg ha^{-1}). Although the CP yield in 2019 was lower than that of 2018, significant differences were observed between the cropping treatments, despite using the same maize cultivar ($p < 0.05$). In 2019, the CP yields were higher in M × S1 (150 kg ha^{-1}) and M × S2 (192 kg ha^{-1}) treatments and the lowest in M × LL treatment (58 kg ha^{-1}). The CP yield was the highest in M × S1 and M × S2 treatments. Similar results have been reported by intercropping maize with hybrid soybean [32,33]. Thus, further investigation on maize–legume intercropping in paddy fields is required for stable feed production.

Table 5. Effects of different cropping treatments on the feed value of legumes in the paddy fields during the summer season

Years	Treatments	NDF (%)	ADF (%)	CP (%)	IVDMD (%)	DDM (%)	DMI (%)	RFV
2018	M × S1	47.7^{a}	36.7^{a}	12.6^{a}	70.3	60.3^{a}	2.52^{a}	118^{a}
	M × S2	55.8^{b}	46.9^{b}	9.87^{b}	62.6	52.3^{b}	2.15^{b}	87.4^{b}
	M × L	47.1^{a}	39.0^{a}	7.91^{b}	72.3	58.5^{a}	2.55^{a}	116^{a}
	SEM	1.06	1.37	0.50	-	1.07	0.05	3.19
2019	M × S1	51.8^{b}	38.7^{a}	12.2^{b}	60.9	58.8^{b}	2.31^{b}	105^{b}
	M × S2	51.6^{b}	40.0^{b}	15.2^{a}	66.6	58.0^{b}	2.33^{b}	105^{b}
	M × L	45.5^{a}	33.2^{a}	8.8^{c}	74.2	63.0^{a}	2.65^{a}	129^{a}
	SEM	0.87	0.77	0.62	-	0.60	0.05	3.29

$^{a-b}$ means the effects within a row without a common superscript letter are significantly different ($p < 0.05$). SEM: standard error of the mean; NDF,: neutral detergent fiber; ADF: acid detergent fiber; CP: crude protein; DDM: digestible dry matter; DMI: dry matter intake; RFV: relative feed value; IVDMD: *in vitro* dry matter digestibility; M × S1, maize and soybean ('Chookdu 1') intercropping; M × S2: maize and soybean ('Chookdu 2') intercropping; M × L: maize and lablab ('Rongai') intercropping.

Table 6. Effects of different cropping treatments on dry matter crude protein yields of maize and soybean in the paddy fields during the summer season

Years	Treatments	Maize (kg ha^{-1})			Soybean (kg ha^{-1})	Total (kg ha^{-1})
		Stalk	Ear	Total		
2018	MM	356^{ns}	364^{ns}	720^{ns}	-	720^{ns}
	M × S1	3413	344	756	244^{a}	1,000
	M × S2	363	418	781	131^{b}	911
	M × L	377	410	787	96^{b}	883
	SEM	0.23	23.1	57.4	11.6	64.0
2019	MM	374^{ns}	328^{b}	702^{b}	0	702^{c}
	M × S1	403	386^{ab}	790^{ab}	150^{a}	940^{ab}
	M × S2	490	407^{a}	897^{a}	192^{a}	1,089^{a}
	M × L	415	385^{ab}	799^{ab}	58^{b}	857^{bc}
	SEM	30.0	14.9	33.4	12.6	42.3

$^{a-b}$ means within a row without a common superscript letter are significantly different ($p < 0.05$). ^{ns} means not significantly different. SEM: standard error of the mean; MM: monocropping maize; M × S1: maize and soybean ('Chookdu 1') intercropping; M × S2: maize and soybean ('Chookdu 2') intercropping; M × L: maize and lablab ('Rongai') intercropping.

Table 7. Effects of different cropping treatments on the total digestible nutrient yield of maize and soybean in the paddy fields during the summer season

Years	Treatments	Maize (kg ha^{-1})			Soybean (kg ha^{-1})	Total (kg ha^{-1})
		Stalk	Ear	Total		
2018	MM	5,028^{ns}	3,697^{ns}	8,725^{ns}		8,725^{ns}
	M × S1	5,134	3,547	8,680	1,065^{a}	9,746
	M × S2	5,006	4,081	9,087	640^{b}	9,727
	M × L	5,292	4,410	9,702	658^{b}	10,360
	SEM	351	393	733	25	738
2019	MM	3,980^{ns}	3,093^{ns}	7,073^{ns}	0	7,073^{b}
	M × S1	4,450	3,726	8,177	724^{ns}	8,900^{a}
	M × S2	4,129	3,622	7,751	735	8,486^{ab}
	M × L	4,483	3,715	8,198	408	8,606^{ab}
	SEM	267	131	311	67.1	348

$^{a-b}$ means within a row without a common superscript letter are significantly different ($p < 0.05$). ^{ns} means not significantly different. SEM: standard error of the mean; MM: monocropping maize; M × S1: maize and soybean ('Chookdu 1') intercropping; M × S2: maize and soybean ('Chookdu 2') intercropping; M × L: maize and lablab ('Rongai') intercropping.

The differences in TDN productivity between the maize monoculture and maize–legume intercropping treatments are shown in Table 7. No significant difference was observed in the TDN content of maize in 2018, similar to that of DM yield. However, in 2018, legume TDN productivity was the highest and lowest in the intercropping treatments with 'Chookdu 1' (1,065 kg ha^{-1}) and 'Chookdu 2' (640 kg ha^{-1}), respectively ($p < 0.05$). In 2019, the TDN productivity of the intercropping treatments did not differ. Nevertheless, the total TDN productivity was the highest in M × S1 (8,900 kg ha^{-1}) intercropping treatment, wherein 'Chookdu 1' recorded the highest DMY (two-year average of 895 kg ha^{-1}). In contrast, the lowest TDN productivity was observed in lablab (533 kg ha^{-1}).

4. Conclusions

In this study, we evaluated the effects of different intercropping systems on the forage yield and nutritive value of maize and legumes in a non-cultivation paddy field. We found that soil properties, nitrogen, available P_2O_5, and K content varied among the cropping systems, and the intercropping treatments outperformed maize monoculture. The DM and TDN yields non-significantly increased in the intercropping treatments, whereas the feed values of the intercropped legumes were significantly higher than that of maize monoculture. Among all the intercropped legumes, 'Chookdu 1' was the most productive (CP and TDN). These findings provide an insight into the role of intercropping systems in improving the forage yield of paddy fields. For stable feed crop production using maize intercropped with legumes in a non-cultivation paddy field, the legume must ensure an excellent moisture resistance mechanism that is favorable for resource competition.

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Conflict of Interests

The authors have no competing interests.

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