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REGULAR ARTICLES

Periodic changes in chemical composition and in vitro digestibility of locally available Gramineae feed resources in the Philippines

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Abstract

Efficient utilization of locally available feed resources is needed for further development of livestock productions in the tropics. However, an inadequate supply of nourish grass is common, and limited information exists regarding the chemical composition and digestibility of locally available feed resources in the different season. There were few reliable information concerning nutritive value of Gramineae resources in dry and rainy seasons in the Philippines. Hence, the present study was conducted to identify the chemical composition and in vitro digestibility of nine kinds of locally available Gramineae feed resources in dry and rainy seasons in the Philippines. The concentration of dry matter (DM), crude protein, and crude fiber of grass samples did not differ among species and seasons. The concentration of organic matter (OM), ether extract (EE), crude ash (CA), nitrogen-free extract (NFE), acid detergent fiber, and neutral detergent fiber (NDF) of grass samples differed significantly among species in both seasons except the NDF in the rainy season. However, the OM, CA, and NDF concentrations of the samples showed no differences between seasons. *Imperata cylindrica* showed the highest concentration of OM among the samples. *Brachiaria brizantha* had the lowest EE concentration among the grasses. The lowest NFE concentration was identified in *Panicum maximum* among the grasses. Although the digestibility of DM (DMD), OM (OMD), and NDF (NDFD) of grass samples showed significant differences among species. The DMD, OMD, and NDFD of *I. cylindrica* were the lowest among the samples, though *Pennisetum purpureum* showed the highest DMD, OMD, and NDFD among the species. Relatively high nutritive values of *P. purpureum* were remarkable among the samples in the present survey area.

Keywords Chemical composition · Digestibility · Natural forage · Philippines

Introduction

In tropical Asian countries, most rural farms are relatively small-scale in size because of limited land area and increasing populations (Chantalakhana and Skunmun 2002). These small-scale farms mostly manage mixed farming systems which produce crops and animals. The farmers graze the animals in crop fields after harvest or before planting, tether the animals during cropping period, or keep the animals in pens for animal managements. Feed resources are the most important materials for animal productions and easily affect animal performances. However, feeding and nutrition have been reported to be the major constraints to animal production in South East Asia (Devendra and Leng 2011). Therefore, much attention to feed resources is necessary for the development of animal production in the area.

When the price of cereal grains was still inexpensive in the past, non-ruminant animal productions were developed well usually in peri-urban areas. However, the price of grains has been risen and gives difficulties to keep moderate number of poultry and swine in good conditions around small-scale farms. Therefore, attentions of small-scale farms shift to develop ruminants which have high potentials to utilize varieties of feed resources. However, two critical periods of feed shortage for ruminants in the rural area were reported

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(Chantalakhana and Skunmun 2002). One of them is the period during the dry and hot season when most ruminants should move a long distance for grazing. The other period is the cropping season when most farm areas are cultivated and leave no area for grazing. Therefore, the efficient utilization of locally available feed resources becomes one of the countermeasures for preventing from the feed shortage.

In the Philippines, many small-scale farms are also crop-based, but livestock play a vital role as source of cash income and draft power. The sale of crops and livestock is a major source of their cash income. Ruminants are usually tethered in vacant areas to graze on natural pasture. Thus, most small-scale farmers rely on locally available feed resources for their animal feed. On the other hand, some cases of the small-scale farms have stall-fed animals. In this case, the farmers try to collect grasses around the farm and supply them to the animals (cut-and-carry system). However, many farmers usually face feed unavailability problems. Since farmers have access to other farmers' grazing area, uncontrolled grazing becomes one of the issues. The farmers also claimed lack of feed due to limited grazing land (Magboo et al. 1998). Therefore, they need to explore and use locally available feed resources efficiently. In addition, the national food self-sufficiency rate of bovine meat in 2013 can be calculated as 73.9% in the Philippines (FAO 2020). Although further developments of meat productions are required to respond to the domestic demands in the country, the productions of livestock rely on backyard farms which are managed in small scale. Distributions of buffaloes, cattle, and goats in the Philippines' backyard farms are 99.6%, 94.1%, and 98.7%, respectively (Philippine Statistics Authority 2019). Thus, efficient utilization of locally available feed resources becomes the most important countermeasures for developing livestock productions in the country (Wanapat et al. 2011; Hung et al. 2013). In addition, the development of a year-round feeding system using the locally available feed resources is required.

There are many herbaceous species as ruminant feed resources in the tropical area, and they have already been studied for their agronomic characteristics and qualities. Gramineae grasses are the most common feed resources for ruminants. The small-scale farmers try to cut and carry the grasses for their animals around a year in the area. However, a wide variation in the quality of the grass supplied to ruminants relies on areas, season, soil condition, and harvesting time (Evitayani et al. 2004a). In addition, an inadequate supply of nourish grass is common and limited information exists regarding the chemical composition and digestibility of locally available feed resources in the different seasons. There were few reliable information concerning the nutritive value of Gramineae resources in dry and rainy seasons in the Philippines. Hence, the present study was conducted to identify the chemical composition and in vitro digestibility of locally available Gramineae feed resources in two different periods divided by the rainfall in the Philippines.

Materials and methods

Location and climate of the study area

This study was conducted in the Science City of Munõz of Nueva Ecija Province located in the central part of Luzon Islands in the Philippines. Natural pastures in Philippine Carabao Center, Department of Agriculture, and Central Luzon State University were selected for collecting locally available Gramineae feed resources. The site is located in the tropical and monsoon region and lies at 15° 71′ N and 120° 90′ E with a mean altitude of 60 m above sea level. The pastures for sample collections were occupied by matured natural grasses and were not fertilized. The soil chemical composition was not analyzed in this study. However, the soils in the survey area were reported to have low P_2O_5 (1.5 ± 9.0 g/kg), SiO_2 (619.7 ± 40.1 g/kg), and K_2O (7.6 ± 3.2 g/kg) contents, but relatively high organic carbon (11.7 ± 6.0 g/kg), total nitrogen (1.0 ± 0.6 g/kg), Al_2O_3 (188.4 ± 28.0 g/kg), Fe_2O_3 (94.1 ± 19.1 g/kg), MnO_2, (2.1 ± 9.0 g/kg), CaO (31.0 ± 9.7 g/kg), and MgO (29.5 ± 12.2 g/kg) contents, as compared with the mean for the surface samples of Asian lowland soils (Miura et al. 1997). In addition, Magahud et al. (2016) reported the pH, OM, available phosphorus, and iron of soil in the survey area as 4.8–5.1, 1.8–3.2%, 2.6–2.8 mg/kg, and 3.1–3.7%, respectively. There are two seasons during a year, the dry season from November to April and the rainy season from May to October. The average monthly temperature, relative humidity, and monthly rainfall of the city ranged from 21 to 28 °C, 73 to 88%, and 1.1 to 181.1 mm during the study period, respectively (World weather online 2020).

Collection and proximate analysis of samples

The locally available feed resources evaluated consisted of nine Gramineae species (*Andropogon gayanus*, *Brachiaria brizantha*, *Brachiaria dictyoneura*, *Brachiaria mutica*, *Brachiaria ruziziensis*, *Imperata cylindrica*, *Panicum maximum*, *Pennisetum purpureum*, and *Themeda triandra*). These grasses were commonly present around a year in the Philippines and easily collected by small-scale farmers around the survey area. The samples from the pasture were collected twice during the dry season (February and May) and twice during the rainy season (July and November) in the survey area. The samples were hand-plucked from the pasture and each species had two samples at the collection. The collected samples were brought to the laboratory of Philippine Carabao Center, Department of Agriculture, on the same day of the collection and were oven dried at 60 °C for 48 h for measuring dry matter (DM) content. The dried samples were milled to pass a 1-mm screen for the proximate analyses. Chemical composition of the samples was measured according to the standard methods of the Association of Official Analytical Chemist (AOAC 2016), including DM, crude protein (CP), ether extract (EE), crude fiber (CF), and crude ash (CA). The organic matter (OM) and nitrogen-free extract (NFE) were obtained using the following formulae: OM (%) = 100 − CA (%), NFE (%) = OM (%) − CP (%) − EE (%) − CF (%). The acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined based on a previously described method (Van Soest et al. 1991).

Determination of in vitro digestibility

In vitro digestibility of DM (DMD), OM (OMD), and NDF (NDFD) of the locally available Gramineae feed resources was determined by the methods of Tilley and Terry (1963). The rumen fluid for measuring in vitro digestibility was collected using an oral stomach tube from healthy mature four Japanese Saanen castrated goats. The goats ate fescue straw, wheat bran, and barley every day. Five hundred milligram of each sample was incubated in the rumen fluid-buffer medium mixture solution at 39 °C for 48 h in an anaerobic condition. After the in vitro digestion trials, the incubated samples were separated from the mixture solution by centrifugation of 2500 rpm for 15 min and dried at 60 °C for 48 h to determine DMD. The OM and NDF contents of the incubated samples were analyzed for showing OMD and NDFD, respectively. The DMD, OMD, and NDFD were obtained using the following formula: DMD or OMD or NDFD = (1 − wi/wo) × 100, where wi = DM or OM or NDF content (mg) of the incubated sample and wo = DM or OM or NDF content (mg) of the original sample.

The experiment was approved and conducted in accordance with the Institutional Animal Care and Use Committee of Meijo University (No. 2014-A-E-13).

Statistical analysis

The mean comparison between species and seasons were compared using probability of differences. Results of the chemical composition and in vitro digestibility were analyzed by Student's *t* test for showing the effect of season and Tukey's multiple comparison test for showing the effect of species. All calculations were made using a commercially available computer program (Excel Statistics; SSRI Co., Ltd., Tokyo, Japan).

Results and discussion

Chemical composition

The chemical composition of the locally available Gramineae feed resources in the study area is shown in Tables 1, 2, and 3. The DM of Gramineae grass samples ranged from 18.6% (*P. purpureum*) to 65.3% (*T. triandra*). The CP content of the grass samples ranged from 3.2% (*B. dictyoneura* and *T. triandra*) to 16.9% (*P. purpureum*). In addition, the CF concentration of the grasses ranged from 27.0% (*B. ruziziensis*) to 49.3% (*P. maximum*). However, the concentration of DM, CP, and CF of the Gramineae grass samples did not differ among species and seasons in the present study ($p > 0.05$). On the other hand, the concentration of OM, EE, CA, NFE, ADF, and NDF of Gramineae grass samples showed differences among species in both seasons ($p < 0.05$) except the NDF in the rainy season. However, the OM, CA, and NDF concentrations of grasses showed no differences between seasons in the present study ($p > 0.05$).

The OM content of grass samples ranged from 85.0% (*P. purpureum*) to 94.1% (*I. cylindrica*) in the dry season and ranged from 83.7% (*P. maximum*) to 94.8% (*I. cylindrica*) in the rainy season. *I. cylindrica* had the highest OM among the grasses in both seasons. The highest OM content of this grass in the present survey was due to low CA content compared to the other grass samples. Göhl (1981) reported the content of ash of this species was from 6.7 to 8.2% that meant the relatively high OM content in this grass species. The reported values can support the results in the present survey. *I. cylindrica* is a perennial grass which can be found mostly on acid soils and occurs generally in damp conditions to swampy area, though the grass has drought resistance (Göhl 1981). This grass species is usually utilized as pasture for ruminants at 15–25 cm height (FAO 2010). However, this species cannot bear heavy grazing and tends to decline or disappear if the pasture was grazed continuously (Andrews 1983). However, this grass is considered as a poor-quality grass in general because of low CP content, energy, and sodium (Falvey 1981; Heuzé et al. 2017a).

The EE concentration of grass samples in the present survey varied from 1.3% (*T. triandra*) to 14.6% (*A. gayanus*) in the dry season and varied from 1.5% (*A. gayanus* and *B. brizantha*) to 10.2% (*B. dictyoneura*) in the rainy season. Since the EE content of *B. brizantha* was 1.4% in the dry season, the low EE concentration of this species in both seasons was remarkable among the grass samples. *B. brizantha* is a perennial grass with 60–200 cm height and can resist continuous grazing. The range of EE content of this grass species in fresh condition was reported to be from 1.2 to 3.3% (Heuzé et al. 2016b). The average values of EE content of this grass species in the present survey agreed with the reported values. On the other hand, *B. dictyoneura* showed relatively high EE

Table 1 Dry matter (DM), organic matter (OM), and crude protein (CP) content of feed resources (%)

	DM			Se	OM†			Se	CP†			Se
	Dry	Rainy	SEM		Dry	Rainy	SEM		Dry	Rainy	SEM	
Andropogon gayanus (Gamba grass)	51.5	29.5	12.8	NS	92.2[a]	91.0[ab]	2.8	NS	4.3	8.3	3.1	NS
Brachiaria brizantha (Brizantha)	42.2	53.1	27.5	NS	92.9[a]	90.5[ab]	1.5	NS	4.7	6.7	2.4	NS
Brachiaria dictyoneura	42.1	26.3	3.6	*	91.2[ab]	91.1[ab]	3.5	NS	3.2	5.9	1.6	NS
Brachiaria mutica (Para grass)	31.3	20.1	8.4	NS	88.1[ab]	87.5[ab]	3.0	NS	9.0	15.2	7.6	NS
Brachiaria ruziziensis (Ruzi grass)	40.8	25.3	9.8	NS	93.1[a]	90.2[ab]	0.7	NS	5.8	10.0	3.7	NS
Imperata cylindrica (Cogon grass)	53.7	38.9	12.8	NS	94.1[a]	94.8[a]	1.2	NS	4.1	4.7	0.9	NS
Panicum maximum (Guinea grass)	33.1	20.2	3.7	NS	88.0[ab]	83.7[b]	2.1	NS	7.9	13.5	4.4	NS
Pennisetum purpureum (Dwarf napier)	22.6	18.6	7.5	NS	85.0[b]	85.2[ab]	2.5	NS	10.2	16.9	7.9	NS
Themeda triandra (Giant themeda)	65.3	36.6	15.3	NS	91.0[ab]	91.8[ab]	0.7	NS	3.2	3.7	1.6	NS
SEM	10.6	15.3			1.8	2.6			3.3	5.3		

† On a dry matter basis. *Se* effect of season in the same species of grass. *$p < 0.05$, *NS* not significant

[ab] Means in the same column with different superscripts are significantly different ($p < 0.05$)

content in the dry season and the highest EE in the rainy season in the present study. This grass species is one of *Brachiaria* species, which are native to East Africa and were introduced to the tropical area (Renvoize et al. 1996). Although nutritional values of this species have not been shown well, the relatively high EE content may become a distinctive characteristic of this grass. The sample of *A. gayanus* showed higher EE content in the dry season than in the rainy season. Although the nutrient conditions of soil were not analyzed in this study, certain changes of soil fertility around the places where this grass was grown might affect the significant difference of EE content between dry and rainy seasons. Further analyses of soil condition are required for showing the exact reasons. On the other hand, *B. dictyoneura*, *B. ruziziensis*, and *P. maximum* had higher EE in the rainy season than in the dry season ($p < 0.05$). The higher content of EE of *P. maximum* in the rainy season than that in the dry season agreed with the results in West Sumatra, Indonesia (1.7% and 3.7% in dry and rainy seasons, respectively) (Evitayani et al. 2004b). In general, a high precipitation tends to suppress maturing the plant and promotes to accumulate nutrients. The high EE content of these grass samples in the rainy season suggests that these species accumulated nutrients during the rainy season. In fact, the contents of CP of

Table 2 Ether extract (EE), crude ash (CA), and nitrogen-free extract (NFE) content of feed resources (% on a dry matter basis)

	EE			Se	CA			Se	NFE			Se
	Dry	Rainy	SEM		Dry	Rainy	SEM		Dry	Rainy	SEM	
Andropogon gayanus (Gamba grass)	14.6[a]	1.5[c]	1.7	*	7.8[b]	9.0[ab]	2.8	NS	30.5[b]	43.1[a]	1.4	*
Brachiaria brizantha (Brizantha)	1.4[c]	1.5[c]	1.2	NS	7.1[b]	9.5[ab]	1.5	NS	51.7[ab]	48.2[a]	8.5	NS
Brachiaria dictyoneura	6.3[b]	10.2[a]	0.7	*	8.8[ab]	8.9[ab]	3.5	NS	44.2[ab]	35.1[abc]	5.4	NS
Brachiaria mutica (Para grass)	3.5[b]	3.1[bc]	1.6	NS	11.9[ab]	12.5[ab]	3.0	NS	41.4[ab]	33.3[bc]	6.2	NS
Brachiaria ruziziensis (Ruzi grass)	2.2[b]	8.0[a]	1.3	*	6.9[b]	9.8[ab]	0.7	NS	58.1[a]	38.5[abc]	2.8	*
Imperata cylindrica (Cogon grass)	2.5[b]	1.6[c]	0.5	NS	5.9[b]	5.2[b]	1.2	NS	50.4[ab]	51.7[a]	3.7	NS
Panicum maximum (Guinea grass)	1.6[b]	4.8[abc]	0.7	*	12.0[ab]	16.3[a]	2.1	NS	29.2[b]	23.8[c]	6.6	NS
Pennisetum purpureum (Dwarf napier)	4.7[b]	4.7[abc]	1.2	NS	15.0[a]	14.8[ab]	2.5	NS	32.5[b]	34.4[abc]	7.1	NS
Themeda triandra (Giant themeda)	1.3[c]	1.9[bc]	1.2	NS	9.0[ab]	8.2[ab]	0.7	NS	48.4[ab]	47.9[a]	3.0	NS
SEM	1.2	1.1			1.8	2.6			6.3	4.4		

Se effect of season in the same species of grass. *$p < 0.05$, *NS* not significant

[abc] Means in the same column with different superscripts are significantly different ($p < 0.05$)

Table 3 Crude fiber (CF), acid detergent fiber (ADF), and neutral detergent fiber (NDF) content of feed resources (% on a dry matter basis)

	CF			Se	ADF			Se	NDF			Se
	Dry	Rainy	SEM		Dry	Rainy	SEM		Dry	Rainy	SEM	
Andropogon gayanus (Gamba grass)	42.7	38.1	5.6	NS	48.7^{ab}	50.8^{abc}	2.6	NS	76.9^{ab}	78.0	1.8	NS
Brachiaria brizantha (Brizantha)	35.1	34.1	3.8	NS	45.8^{ab}	46.9^{bc}	2.1	NS	75.2^{ab}	76.5	1.8	NS
Brachiaria dictyoneura	37.5	40.0	5.0	NS	49.0^{ab}	51.7^{a}	2.8	NS	75.7^{ab}	80.6	3.0	NS
Brachiaria mutica (Para grass)	34.2	36.0	5.8	NS	41.3^{ab}	51.5^{ab}	1.2	*	69.4^{b}	76.1	5.3	NS
Brachiaria ruziziensis (Ruzi grass)	27.0	33.7	7.4	NS	38.5^{b}	42.4^{c}	5.8	NS	71.3^{ab}	66.8	6.1	NS
Imperata cylindrica (Cogon grass)	37.1	36.7	2.2	NS	50.2^{ab}	55.9^{a}	2.4	NS	79.4^{a}	82.6	1.5	NS
Panicum maximum (Guinea grass)	49.3	41.7	7.0	NS	54.3^{a}	54.0^{ab}	3.0	NS	79.0^{a}	74.4	2.7	NS
Pennisetum purpureum (Dwarf napier)	37.7	29.1	8.1	NS	42.4^{ab}	45.9^{bc}	4.5	NS	73.6^{ab}	76.7	6.0	NS
Themeda triandra (Giant themeda)	38.2	38.2	0.6	NS	55.4^{a}	49.3^{abc}	1.1	*	80.3^{a}	77.9	1.4	NS
SEM	5.3	5.8			3.9	2.2			2.4	4.8		

Se effect of season in the same species of grass. *$p < 0.05$, *NS* not significant

[abc] Means in the same column with different superscripts are significantly different ($p < 0.05$)

these grass samples also showed higher average values in the rainy season than in the dry season, though the difference was not significant.

The NFE content of grass samples ranged from 29.2% (*P. maximum*) to 58.1% (*B. ruziziensis*) in the dry season and ranged from 23.8% (*P. maximum*) to 51.7% (*I. cylindrica*) in the rainy season. The lowest NFE concentration of *P. maximum* among the grass samples was identified in both seasons. *P. maximum* is a major perennial grass which can fit for tropical pasture, cut-and-curry, hay, and silage (FAO 2010). This grass can be taken well by all grazing livestock with high palatability especially in young leaf (Cook et al. 2005). Göhl (1981) reported that the NFE contents of this grass species in fresh were from 43.1 to 48.5%. The NFE contents of the grass in the present survey were lower than the reported values. The relatively higher concentration of the other nutrients such as CP, CF, and CA in the present collected samples occurred the lower NFE. Since the NFE content of *I. cylindrica* was 50.4% in the dry season, the high NFE concentration of this species in both seasons was remarkable among the grass samples. This grass was reported to be palatable when the grass was cut frequently (Soerjani 1970). Relatively high NFE concentration of this grass may induce the high palatability. *A. gayanus* had lower NFE in the dry season than in the rainy season ($p < 0.05$). The lower NFE content in the rainy season might be induced by the higher EE content of the grass in the season. *A. gayanus* is a perennial grass which can grow up to 200 cm height (Göhl 1981). This grass can grow on a wide variety of soils in areas where annual precipitation is from 600 to 1100 mm and a dry season with 5 to 6 months. On the other hand, *B. ruziziensis* had higher NFE in the dry season than in the rainy season ($p < 0.05$). Seasonal alternations in the tropical area are identified and are shown by the age and maturity of grass species with season change from the dry to rainy seasons.

The range of fiber fraction such as ADF and NDF contents in the dry season was from 38.5% (*B. ruziziensis*) to 55.4% (*T. triandra*) and from 69.4% (*B. mutica*) to 80.3% (*T. triandra*), respectively. In the rainy season, the ADF and NDF concentrations varied from 42.4% (*B. ruziziensis*) to 55.9% (*I. cylindrica*) and from 66.8% (*B. ruziziensis*) to 82.6% (*I. cylindrica*), respectively. The lowest ADF content in *B. ruziziensis* was identified in both seasons. Heuzé et al. (2017b) reported the ADF content of the aerial part of this grass species was from 31.9 to 45.2%. The relatively lower ADF contents of this grass in this survey agreed with the reported values. On the other hand, the highest ADF and NDF contents in *T. triandra* were identified in the dry season. Heuzé et al. (2015) reported the average contents of ADF and NDF were 39.4% and 69.0%, respectively. The ADF and NDF contents of the grass species in this survey were higher than the reported values. *T. triandra* called as Giant themeda in the Philippines is a palatable and high nutritive grass when the grass is in a young stage. This grass can be adopted as a grazing grass for domestic animals. *T. triandra* had higher ADF in the dry season than in the rainy season ($p < 0.05$). On the other hand, *B. mutica* had lower ADF in the dry season than in the rainy season ($p < 0.05$). Since the CF concentration of these grass species did not show a significant difference between the seasons, cellulose content might have been changed in the different seasons. *B. ruziziensis* and *B. mutica* are perennial grasses with high palatability and nutritive values. These species are the major tropical grasses as *Brachiaria* genus with *B. brizantha*. *B. mutica* was reported to be possible to obtain 24 t DM/ha/year under irrigation in the Philippines (Furoc and Javier

1976). In addition, the NDF concentrations of this grass species were reported to be from 56.8 to 86.2% (Heuzé et al. 2018). However, the change of season to dry affected adversely the nutritive values with increasing NDF (Tedonkeng Pamo et al. 2007). The average values of NDF concentration in *B. ruziziensis* and *B. mutica* in the present survey were higher than the reported values. In the rainy season, the highest ADF and NDF contents were identified in *I. cylindrica.* Heuzé et al. (2017a) reported the ADF and NDF contents of this grass were from 41.5 to 46.8% and from 70.1 to 77.2%, respectively. The ADF and NDF contents of the grass species in this survey were higher than the reported values.

In vitro digestibility

The DMD, OMD, and NDFD of the locally available Gramineae feed resources in the study area are shown in Table 4. All the digestibility of Gramineae grass samples showed differences among species in both seasons ($p < 0.05$). In the dry season, the DMD ranged from 19.7% (*I. cylindrica*) to 47.1% (*P. purpureum*), while in the rainy season varied from 17.6% (*I. cylindrica*) to 46.5% (*P. purpureum*). The OMD of Gramineae grasses ranged from 23.9% (*I. cylindrica*) to 48.5% (*P. purpureum*) in the dry season and ranged from 17.8% (*I. cylindrica*) to 49.9% (*P. purpureum*) in the rainy season. The NDFD of Gramineae grasses ranged from 18.0% (*I. cylindrica*) to 52.9% (*P. purpureum*) in the dry season and ranged from 14.4% (*I. cylindrica*) to 49.5% (*P. purpureum*) in the rainy season. In both seasons, *I. cylindrica* had the lowest DMD, OMD, and NDFD. On the other hand, *P. purpureum* had the highest DMD, OMD, and NDFD in both seasons. *I. cylindrica* is considered as a poor-quality grass in general. The low digestibility of this species identified the evidence of low quality. Tendonkeng et al. (2015) reported the in vitro DMD of *I. cylindrica* straw using goat rumen fluid was 25.6%. The DMD of the same grass sample in the present study was lower than the reported value. In addition, the NDFD of the grass sample in this study was less than 20%. Padma et al. (2013) showed that the methanolic extract of this grass species had 12.5 mg/g of tannic acid. In general, tannins have the ability to reduce the digestibility of the diet (Frutos et al. 2004). The relatively high presence of tannins in this grass species might have induced the low digestibility in this study. On the other hand, *P. purpureum* is a well-known tropical grass in the world. This species has a high productivity and can be used as pasture, hay, and silage in ruminant productions. This grass has a relatively high CP content and rich in fiber. The NDF of this species varied from 55 to 75% (Moran 2011). The OMD of this grass species in ruminants was reported to range from 55.4 to 70.6% (Heuzé et al. 2016a). In addition, Evitayani et al. (2004b) showed that the OMD of *P. purpureum* was 61.9% and 62.3% in dry and rainy seasons, respectively. The results in the present study were lower than the reported values. Kozloski et al. (2005) reported that DM, OM, NDF, and lignin contents of this specie's hay did not differ with maturation, but ADF and non-structural carbohydrates increased linearly with growth. The growth stage of this grass sample might be matured one during the sample collection. Heuzé et al. (2016a) reported that the ADF content of *P. purpureum* was from 29.5 to 52.9%. In addition, Evitayani et al. (2004b) showed the same grass had 38.7% and 28.5% in dry and rainy seasons, respectively. The sample of *P. purpureum* had a rather high ADF and might affect the lower OMD in the present study. The DMD of *B. brizantha* and *T. triandra* were higher in the rainy season than that in the

Table 4 In vitro digestibility of feed resources (%)

	DM			Se	OM			Se	NDF			Se
	Dry	Rainy	SEM		Dry	Rainy	SEM		Dry	Rainy	SEM	
Andropogon gayanus (Gamba grass)	31.6^{b}	27.1^{b}	3.0	NS	35.4^{b}	30.4^{ab}	3.6	NS	30.3^{bc}	31.8^{ab}	5.0	NS
Brachiaria brizantha (Brizantha)	39.2^{ab}	45.7^{a}	0.9	*	42.3^{a}	43.0^{a}	1.7	NS	38.0^{ab}	42.2^{a}	2.4	NS
Brachiaria dictyoneura	41.2^{a}	41.7^{a}	1.6	NS	44.4^{a}	45.1^{a}	3.2	NS	42.5^{ab}	47.1^{a}	2.7	NS
Brachiaria mutica (Para grass)	37.8^{bc}	44.9^{a}	4.5	NS	42.5^{a}	46.9^{a}	5.9	NS	32.2^{bc}	48.2^{a}	6.2	*
Brachiaria ruziziensis (Ruzi grass)	39.4^{ab}	35.6^{a}	8.4	NS	43.5^{a}	40.6^{a}	10.9	NS	28.2^{bc}	30.4^{ab}	13.5	NS
Imperata cylindrica (Cogon grass)	19.7^{d}	17.6^{b}	2.7	NS	23.9^{b}	17.8^{b}	1.8	*	18.0^{c}	14.4^{b}	2.4	NS
Panicum maximum (Guinea grass)	33.4^{b}	37.3^{a}	3.1	NS	36.1^{b}	45.1^{a}	1.9	*	35.8^{ab}	36.3^{ab}	4.8	NS
Pennisetum purpureum (Dwarf napier)	47.1^{a}	46.5^{a}	2.8	NS	48.5^{a}	49.9^{a}	2.9	NS	52.9^{a}	49.5^{a}	4.0	NS
Themeda triandra (Giant themeda)	22.3^{d}	37.0^{a}	1.8	*	27.6^{b}	37.2^{ab}	4.7	NS	22.7^{bc}	37.0^{a}	4.6	*
SEM	5.7	9.2			5.2	8.4			7.4	9.5		

Se effect of season in the same species of grass. *$p < 0.05$, *NS* not significant

[abc] Means in the same column with different superscripts are significantly different ($p < 0.05$)

dry season ($p < 0.05$). The higher DMD in the rainy season compared to the dry season was reported in some varieties of grass species by Nasrullah et al. (2003) and Evitayani et al. (2004b). Bula et al. (1977) reported that DMD of forage had a relationship with changes in the chemical composition such as fiber, lignin, and silica contents. On the other hand, the OMD of *I. cylindrica* was lower in the rainy season compared to the dry season, though the OMD of *P. maximum* was higher in the rainy season than in the dry season. Since the analyzed chemical composition of *I. cylindrica* in the present survey did not show significant differences between the seasons, the lignin content of this grass species might be higher in the rainy season. On the other hand, *P. maximum* had higher EE that might be promoted to accumulate nutrients in the rainy season. The digestible nutrients in this grass species were accumulated in the rainy season and induce higher OMD in the rainy season than in the dry season. The NDFD of *B. mutica* and *T. triandra* were higher in the rainy season than that in the dry season ($p < 0.05$). According to the average values of CF, ADF, and NDF contents of the *B. mutica* sample, the rate of CF in ADF or NDF can be calculated. The rate of CF/ADF was 82.8% and 69.9% in dry and rainy seasons, respectively. In addition, the rate of CF/NDF was 49.3% and 47.3% in dry and rainy seasons, respectively. Thus, both rates in the grass sample were lower in the rainy season than in the dry season. Since CF contains cellulose and insoluble lignin, the low CF/ADF and CF/NDF rates of the grass sample might cause the higher NDFD of the sample in the rainy season. On the other hand, the hemicellulose of *T. triandra* can be calculated as 24.9% in the dry season and 28.6% in the rainy season using the average values of ADF and NDF. Since hemicellulose can be digested easily, the higher hemicellulose content of the grass sample might induce the higher NDFD of the sample in the rainy season. *T. triandra* also had a higher DMD in the rainy season than in the dry season ($p < 0.05$). The availability of *B. mutica* and *T. triandra* as a feed resource in the rainy season is remarkable compared to that in the dry season. It was suggested that varieties in nutrient digestibility might have been related to differences in the chemical composition of the grasses, species, and environmental factors (Evitayani et al. 2004a).

Conclusions

The results of the present study evaluated nutritive values of different locally available Gramineae grasses in the Philippines. Based on our data, it could be concluded that each grass has different nutrient composition and digestibility in dry and wet seasons in the country. In particular, relatively lower nutritive value of *I. cylindrica* and relatively higher nutritive value of *P. purpureum* are remarkable in the present study. In addition, *B. dictyoneura* and *P. purpureum* have relatively high digestibility in this study. The good combination of these grass as feed resources in each season is important for ruminant production in the Philippines. Further investigations for evaluating the nutritive values of grasses in different areas of the country are necessary.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Statement of animal rights The experiment was approved and conducted in accordance with the Institutional Animal Care and Use Committee of Meijo University.

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