Asian Journal of Agriculture and Food Sciences (ISSN: 2321 – 1571)
Volume 05 – Issue 03, June 2017

Biometrical Ranking of Fodder Crops for Sustainable Livestock and Clean Air Production

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ABSTRACT— ***The study was conducted with the objectives to develop a professional forage quality ranking scale by considering their efficiency of biomass production (X_{ddm}), animal production response (X_{ap}), enteric methane emission reduction (X_{CH4}) and benefit to cost ratio of their production (X_{bc}) in proportion to a typical fodder: maize, considering its constant efficiency of 1.0. Available fodder crops were cultivated following standard agronomical practices and conserved to develop database for calculating X_{ddm}, and X_{bc}. Considering maize as a control roughage, a series*** of ***feeding trials on the native cattle of Bangladesh was conducted to calculate X_{ap} and X_{CH4}. The maize index (M_i) of a test fodder crop was calculated as: $M_i = \frac{Xddm + Xap + XCH4 + Xbc}{4}$. The M_i of Moringafeed was found the highest (1.64), followed by Maize (1.00), Australian sweet jumbo (0.99) and Napier- Bajra (0.82). The German, Napier-Hybrid, Napier Arusha and Andropogon had the M_i of between 0.80 and 0.50 (0.72, 0.63, 0.57 and 0.50, respectively). Next, the M_i of Sugargraze jumbo, Splendida, UMS (Aus), and Para fall between 0.49 and 0.40 (0.45, 0.43, 0.42, 0.41 and 0.40, respectively). The least Mi (below 0.40) was found in UMS (Aman), local grass and Plicatulum (0.39, 0.35 and 0.35, respectively). The M_i of UMS (Aman), local grass and Plicatulum was below 0.40. The M_i may be used for the ranking of fodder crops for their cost effective production and feeding to animals and help reduction of enteric methane emission in the rumen.***

Keywords— Maize index, biomass production, enteric methane, emission factor

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1. INTRODUCTION

The availability of quality forages, in addition to their biomass yield, is one of the important factors support sustainable livestock and clean air production avoiding food-feed competitions and reducing feed costs, gyrate up to 89% of recurring costs [1, 2] of animal farming. Different varieties of rice (*Oryza sativa*) straws, fodder maize (*Zea mays*), Napier (*Pennisetum pupureum*) cultivars and Sorghum (*Sorghum bicolour*) are mostly available to the farmers of the south and south-east Asia for feeding their ruminant animals. The quality varies greatly among and within forage crops [3] and differences in cultivars, season of production, soil health, and agronomical practices affect the nutritive values of roughages [4, 5, 6] . Similarly, the feeding response to production and productivity of animals and enteric methane emission in the rumen are also affected by forage quality [7, 8, 9]. Huque *et al.* [10] reported that the enteric methane emission in the rumen per kilo milk (Kg CH_4/Kg Milk) of the cows raised in a good feed base (0.035) was significantly ($p<0.00$) lower than that was raised in a poor feed base (0.07). The benefit to cost ratio of biomass production of forage varied on the type of cultivars of forage crops and their cropping systems [11].

At a backdrop of gradual transformation of subsistence livestock farming into input supported systems in addition to cultivation of conventional fodder crops a range of new forage crops are being introduced through seed markets. The absence of database and information of their nutritional quality and response to animals of the newly introduced forages often exploit users. The database may support the development of their ranks or grades according to their nutritive values, and may help farmers to select suitable forage crops for their uses. It may also support concerned seed certification authorities to release seeds of suitable forage crops in an agro-ecological area. The relative feed value (RFV), a tool for determining hay and forge quality and their market price, was developed by the Hay Marketing Task Force of the American Forage and Grassland Council [12] calculating their intake and digestibility depending on NDF and ADF contents. Similarly, nutritional weight of forages calculating their relative values of digestible organic matter to that of Maize silage was predicted and used for them to be ranked accordingly by Huque and Sarker [13]. Feeding response to animals and energy losses due to enteric methane emission in the rumen in the above forage ranking systems was not considered. However, an easy to use ranking system of available forage crops considering their relative values of biomass yield, animal production efficiency, reduction efficiency of enteric methane emission in the rumen and benefit to cost ratio of their cultivation may facilitate farmers and development workers to select suitable forage crops for the cost effective and climate resilient livestock production minimizing pollution of climate to some extent. Thus, the present research work was undertaken to develop a database on the production efficiency of biomass, daily live weight gain of growing bulls, benefit to cost of fodder cultivation and the reduction efficiency of enteric methane emission in the rumen of available fodder cultivars, and the mathematics of their relative values among different cultivars of forages for devising their ranking system integrating the above biological attributes.

2. MATERIALS AND METHODS

2.1. Fodder Cultivation and Silage Preparation of Fibrous Feeds

Rice straw of Aus (harvest in July and August) and Aman (harvest in November and December) were procured and impregnated with urea and molasses solution of water (UMS) following the method described by Huque and Talukder [14] , and it, being practiced by farmers, was considered to be compared as fibrous feeds with other fodder crops. Fodder crops available in the fodder germplasm bank of the Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka and the cultivars extended to farmers were cultivated in its research field in the Modhupur tract agroecological zone following recommended agronomical practices for each of them. The biomass was harvested at their optimum maturity and conserved following ensiling process different fodder crops. Moringa was cultivated and lopped branches with leaves (tops) were chopped and dried in the sun, milled mechanically, dried and conserved as Moringafeed in synthetic bags. The other graminaceous perennial fodder crops (Napier of different cultivars, Andropogan, Splendida, Plicatulum) were cultivated, harvested and ensiled in underground pits. The German grass or Para were cultivated in low lying lands and considering farmers practice their freshly harvested biomass was fed to animals. The seeds of Maize, Sugargraze-Jumboo, Jumboo green and Australian Sweet Jumbo were procured from the local market and they were cultivated in the fodder field of the BLRI, the biomass produced was harvested at recommended maturity and ensiled for feeding to animals. Maize was harvested with cobs at their dough stage and ensiled. All the data on the production of biomass and its loss during the harvest and conservation or cost of production and market price were collated. The fresh dry matter (DM) of different fodder biomass was determined according to AOAC [15].

2.2. Feeding Trials

Ensiled Maize fodder was considered to be a control roughage feed. A diet of sole Maize silage was considered as the control during the feeding trials conducted on the different roughages on the growing native bulls with an average live weight (LW) of 146 (±22) kg in different trials conducted over a period of last five years (2010 to 2015). Each of the roughage diet was fed to six bulls, and the duration was at least 60 days including a 7 days digestibility trial. After recording initial live weight (LW), the bulls under each trial were weighed at ten days interval, feed offered and refused was weighed daily with a continuous adjustment of ad libitum DM intake by supplying at least 10% additional roughage. The feces and feed refusal of an individual bull were weighed and recorded during the digestibility trial period. Representative feed, feces and refusal samples were collected and preserved for their DM determination according AOAC [15]. The intake and digestibility of feed DM was calculated accordingly. The cumulative LW of bulls was regressed on the growth period of animals and the slope of the regression line was calculated to be the average daily weight gain of the animals. The gross energy (GE) of a fodder crop was determined using a Bomb Calorimeter (IKAØ Calorimeter System C5003 Control, USA) of the Nutrition Lab of the BLRI.

2.3. Mathematical Calculations

All the data were inserted in spreadsheets of Microsoft Excel using a computer for determining the secondary data, extrapolation of information and calculating necessary mathematics:

2.3.1. Biomass production efficiency (X_{ddm})

The harvest of fodder biomass was expressed in DM yield per hectare (DMY) following the formula: DMY = $\frac{\text{Fodder biomass yield (kg)} * \text{\% fresh DM of the biomass} * 10000}{\text{Area of land in square meter}}$ kg/ha. The harvest loss (HL) of a fodder crop was the proportion of biomass lost during mowing, transportation and ensiling process, and it was calculated according to following formula: HL = $\frac{[\text{DM harvested} - \text{DM ensiled}] + (\text{\% loss of ensiled fodder} * \text{DM ensiled}) * 100}{\text{DM harvested}}$ %. The refusal loss of a fodder was important and it was the feed refused by an animal during the feeding period. It was excluded in the calculation of digestibility (D, %) of a fodder. It was calculated according to formula: D = $\frac{(\text{DM offered} - \text{DM refused} - \text{DM voided in feces}) * 100}{\text{DM offered}}$ %. Thus, the digestible DM (DDM) yield of fodder crops of a hectare of land (Y_{ddm}) was calculated by the following equation: $Y_{ddm} = (\text{DMY} - \text{DMY} * \text{\% HL}) * \text{\% D}$ kg/ha. Finally, the Y_{ddm} of maize was considered as the denominator to calculate DDM production efficiency of a fodder crop (X_{ddm}), and it was expressed as $X_{ddm} = \frac{\text{Yddm of a fodder}}{\text{Yddm of maize}}$.

2.3.2. Animal Production Efficiency (X_{ap})

The animal production efficiency of fodder crops were calculated by determining the D and the intake of DM (DMI) of each fodder and their response to daily LW gains (LWG). The yield of LW per hectare of land (Y_{ap}) and the ratio of fodder to maize for LW production (X_{ap}) were determined using the following formula: $Y_{ap} = \frac{LWG\ (kg) * DDM\ (kg)}{DMI\ (kg) * D(\%)}\ kg/ha$; and $X_{ap} = \frac{Yap\ of\ fodder}{Yap\ of\ maize}$.

2.3.3. Rumen Enteric CH_4 Emission Reduction Efficiency (X_{CH4})

The enteric CH_4 emission in the rumen of animals fed different types of fodder crops was calculated from the daily gross energy intake (GEI) of an animal according to the equations of the IPCC [16], under Tier 2. The daily GEI was calculated based on daily DMI of a fodder crop and its GE content (MJ/kgDM). Thus, the daily GEI was calculated by multiplying the daily DMI with the GE value of fodder DM. The emission factor (EF) was calculated using the IPCC equation (IPCC, 2006): $EF = \frac{GE.[\frac{Ym}{100}]}{55.65}$ Kg CH_4/head/day; where Ym is 6.50%. The EF was divided by daily LWG to calculate methane emission per kg LWG ($Y_{CH4} = \frac{CH4\ emission, kg/d}{LWG\ (\frac{kg}{d})}$). In case of LW loss, positive values of Y_{CH4} was considered for following calculations, because enteric methane production as a biological phenomenon cannot be a negative value. Finally, the reduction efficiency of enteric CH_4 emission (X_{CH4}) of a fodder crop was calculated to be the ratio of CH_4 emission from per kg LWG of maize feeding to the same of a test fodder, and it was calculated using the equation of $X_{CH4} = \frac{YCH4\ of\ Maize}{YCH4\ of\ fodder}$.

2.3.4. Benefit to Cost Efficiency (X_{bc})

The production cost per hectare of each fodder consists of the cost of cultivation (seed, land & land preparation, fertilization, irrigation, intercultural operation, transportation, labour etc), and processing (harvest, milling, ensiling/drying, packing, labour etc). The total annual gross cost of a fodder (GC_f) per hectare was calculated according to the following equation: $GC_f = \sum_{i=1}^{f}(P_i \times Q_i)$; Where P_i = The price of i^{th} input; Q_i = The quantity of i^{th} input. The gross return of the fodder GR_f was calculated following the equation: $GR = Q_f \times P_f$; where Q_f is the quantity of product and, P_f is the price of the product of a hectare of land. The benefit to cost ratio of fodder crops (y_{bc}) was calculated by dividing GR_f with GC_f ie, $y_{bc} = \frac{GR_f}{GC_f}$. Finally, the benefit to cost efficiency of a fodder crop (X_{bc}) was calculated to be the ratio of y_{bc} of a fodder to that of maize according to the following equation: $X_{bc} = \frac{Ybc\ of\ fodder}{Ybc\ of\ maize}$. All the cost was converted into US$ considering average exchange rate of 1US$= 78.0 Bangladesh Taka (BDT) during the study period.

2.3.5. Maize Index (M_i)

The efficiency of biomass production of a fodder crop (X_{ddm}), animal production (X_{ap}), reduction of enteric CH_4 emission in the rumen (X_{CH4}) and the benefit to cost of a fodder (X_{bc}) are the arithmetic ratio of different production parameters of Maize and a fodder crop. Giving an equal weight to the four different types of efficiencies of a fodder crop, the arithmetic average of the four efficiencies was termed as the maize index (M_i) of available fodder in the region of production. Thus, the Mi of a fodder crop was calculated using the equation of $M_i = \frac{Xddm + Xap + XCH4 + Xbc}{4}$. The RFV of fodder crops was also calculated by their digestibility and DM intake (%LW) [12].

2.4. Statistical Analysis of Data

The primary data of different crops were tabulated with their average values and standard deviation. After calculation of M_i of the fodder crops the correlation and regression of M_i of all the tested fodder crops with their DDM yield (kg/ha), LW production of animals (kg/ha), methane production per kg gain of animals, or with benefit to cost were determined and the significance of r values were compared with the tabulated r values at 5.0% level of significance [17].

3. RESULTS AND DISCUSSION

3.1. Biomass Production and Animal Production Efficiency of Fodder Crops (X_{ddm} and X_{ap})

The different parameters of biomass and animal production efficiencies and calculated X_{ddm} and X_{ap} of different fodder crops (kg/ha) are summarized in Table 1. It shows that DMY of different fodder crops ranged from 5000 kg/ha in local grass to 35000 kg/ha in Moringa with an average of 17488.6 kg/ha. Different fodder crops had variations in their botanical and genotypes and they may have resulted in their yield variations, as all of them, except the local grass, were cultivated in a single agro-ecological zone (Modhupur Tract) of the country following their specific agronomical practices. The local grasses were of mixed biomass of most gramineous types. They were available in a single area without any agronomical interventions of their natural habitat, and were collected and fed daily to the animals following farmers` practices. The annual biomass production (DM) of different Napier cultivars was found to range from 27.1 to 58.4 t/ha [18], and that of Maize, Australian sweet jumbo and Moringafeed was 24.93, 23.42 and 45.0 t/ha, respectively [19]. The HL ranged from 1.0% in local grass to 30.0% with an average of 6.81 % of the total production. It depends on farm practices and the processing systems. Aus straw is produced in the monsoon, frequent and continuous rainfall often make farmers unable to preserve straw by sun drying and result in the loss of moldy and rotten wet straw. This resulted in a higher harvest loss of rice straw.

The average D (%) of different fodders was 50.93 %, ranging from 39.0 % of Napier Arusha to 62.7 % of Moringafeed. The apparent DM digestibility of maize, Australian sweet jumbo and moringafeed was reported to be 69.63, 53.83 and 62.67 %, respectively [19], and that of Andropogon harvested at 140 days of re-growth was 54.2% [20]. *In- vitro* DM digestibility of rice straw was found to be 59.4 % [21]. The digestibility of Jumboo grass and silage (*Sorghum bicolor*) was reported to be 56.7 and 55.5 %, respectively in lactating Nili Ravi buffaloes when the diet was supplemented with 25 % concentrate on DM basis [22]. Considering the DMY, HL and D the average Y_{ddm} (kg/ha) of fodder was 8729.2 with a maximum of 21726 in Moringafeed and a minimum of 1709 in UMS (Aus rice). The calculated X_{ddm} of different fodder ranged from 0.14 of Aus rice straw to 1.83 of Moringafeed with an average of 0.73 (Table 1).

Table 1. Biomass production and animal production efficiency of fodder crops

Name of fodder crops	**Biomass Production Efficiency**					**Animal Production Efficiency**			
	DMY, kg/ha	**HL %**	**D, %**	**Y_{ddm}, kg/ha**	**X_{ddm}**	**DMI, kg/d**	**LWG, kg/d**	**Y_{ap} kg/ha**	**X_{ap}**
Local grass	5000	1	41.5	2054	0.17	4.18	0.184	217.9	0.11
Plicatulum	13000	5	55.3	6830	0.57	4.28	0.05	144.3	0.07
Napier-Bajra	24014	8	49.2	10870	0.91	4.14	0.296	1579.6	0.80
Napier-Aurosha	19454	7	39	7056	0.59	2.86	0.139	879.3	0.44
Napier-Hybrid	25000	7	50.2	11672	0.98	2.93	0.081	642.7	0.32
Andropogan	18000	6	47.1	7969	0.67	3.7	0.125	571.6	0.29
Splendida	17000	6	44.5	7111	0.60	3.33	0.083	398.3	0.20
Maize	20700	3	59.2	11887	1.00	2.72	0.269	1985.8	1.00
Sugargraze-Jumboo	17000	3	53	8740	0.74	2.25	0.04	293.2	0.15
UMS (Aman straw)	7500	20	45.5	2730	0.23	2.52	0.04	95.2	0.05
UMS (Aus straw)	5500	30	44.4	1709	0.14	2.77	0.075	104.2	0.05
Moringafeed	35000	1	62.7	21726	1.83	3.1	0.376	4202.7	2.12
Australian Sweet Jumboo	23400	3	51.0	11576	0.97	2.38	0.218	2079.1	1.05
Jumboo green	14400	3	53.8	7515	0.63	3.12	-0.148	-662.6	0.33
Para	15250	3	54.2	8018	0.67	2.43	-0.132	-803.5	-0.40
German	19600	3	64.2	12206	1.03	2.83	0.107	718.8	0.36
Average	17489	6.81	50.9	8729	0.73	3.10	0.11	777.9	0.39
SD	7721	7.63	7.3	4856	0.41	0.66	0.14	1216.2	0.61

DMY, dry matter yield; HL, harvest loss; D, digestibility; Y_{ddm}, digestable dry matter yield; X_{ddm}, biomass production efficiency of fodder crops; DMI, dry matter yield; LWG, live weight gain; Y_{lw}, live weight yield; and X_{ap}, animal production efficiency of fodder crops.

The average DMI of different fodder was 3.10 kg/d and they varied from 2.25 of Sugargraze (jumboo) to 4.28 kg/day of Plicatulum. The response of feeding of different fodders to daily LWG was 0.11 kg/d, and it ranged from 0.04 kg/d of Sugargraze (Jumboo) to 0.376 kg/d of Moringafeed, respectively. The average Y_{ap} was found to be 777.9 kg/ha with a highest of 4203 kg/ha in Moringafeed and a lowest of 95 kg/ha in UMS (Aman rice). The average X_{ap} of fodder crops was 0.39, and it ranged from 0.05 of UMS (Aus or Aman rice) to 2.12 of Moringafeed, respectively.

3.2. Enteric Methane Emission Reduction Efficiency of Fodder Crops (X_{CH4})

The data of different fodders and their calculated X_{CH4} is presented in Table 2. The average GE (MJ/kgDM) of different fodders was 16.2 and it ranged from 14.74 in Para grass to 17.8 MJ/kgDM in Morngafeed. The highest GEI of 68.48 MJ/d of bulls was found in Plicatulum and that of the lowest of 37.80 MJ/d was found in Sugargraze with an average intake of 50.14 MJ/d. Similarly, the highest value of enteric CH_4 was 0.078 kg/d for Plicatulun and the lowest of 0.044 for Sugargraze, and the average was calculated to be 0.06 kg/d. The enteric methane emission in the rumen per kg LWG, an indicator of the extent of climate pollution by different fodder was calculated and it ranged from 0.17 kg in Moringafeed to 1.60 kg in Plicatilum. The average of tested fodder crops (Y_{CH4}) was 0.59 kg. The average enteric CH_4

emission reduction efficiency in relation to maize (X_{CH4}) was calculated to be 0.52 varying from 1.21 in Moringafeed to 0.13 in Plicatilum. It means that the emission of enteric CH_4 due to one kg LW of fodder maize feeding (0.21 kg CH_4/kg LWG) was as low as 13.0 % of that produced by Plicatulum (1.6 kg CH_4/kg LWG), and as high as 121.0% of that produced by Moringafeed (0.17 kg CH_4/kg LWG). The different variety of Napier comprises of different botanical compositions and variations in stem to leaf ratios [23], and their chemical compositions affect the emission of enteric CH_4. The relationship between LWG of animals and, enteric methane emission and LWG ratio **(Y_{CH4})** is presented in Figure 1. It shows a strong correlation between the parameters ($y = 0.071LW\ gain^{-0.90}$, r = 0.96, df=15). It means that when the animal growth performances increases, its enteric methane emission per kg LWG reduces significantly (P<0.001). The variation in the growth responses of the animals was an important factor that dictates the ratio of methane emission per unit of LWG in the rumen [24, 25 and 26].

Table 2. Enteric CH_4 emission reduction efficiency of different fodder crops

Name of fodder crops	GE MJ/kgDM	GEI, MJ/d	LWG, kg/d	EF, kg CH_4/d	Y_{CH4} (CH_4:LWG)	XCH_4
Local grass	15.8	66.04	0.184	0.08	0.42	0.50
Plicatulum	16	68.48	0.050	0.08	1.60	0.13
Napier-Bajra	16	66.24	0.296	0.08	0.26	0.80
Napier-Aurosha	15.7	44.90	0.139	0.05	0.38	0.55
Napier-Hybrid	16	46.88	0.081	0.05	0.68	0.31
Andropogan	16.3	60.31	0.125	0.07	0.56	0.37
Splendida	16.7	55.61	0.083	0.06	0.78	0.27
Maize	17.6	47.87	0.269	0.06	0.21	1.00
Sugargraze-Jumbo	16.8	37.80	0.040	0.04	1.10	0.19
UMS (Aman rice straw)	15.8	39.82	0.040	0.05	1.16	0.18
UMS (Aus rice straw)	15.8	43.77	0.075	0.05	0.68	0.30
Moringafeed	17.8	55.18	0.376	0.06	0.17	1.21
Australian Sweet Jumboo	17.05	40.58	0.218	0.05	0.22	0.96
Jumboo green	16.2	50.54	-0.148	0.06	0.40	0.52
Para	14.74	35.82	-0.132	0.04	0.32	0.66
German	14.98	42.39	0.107	0.05	0.46	0.45
Average	16.20	50.14	0.113	0.06	0.59	0.0.52
SD	0.83	10.67	0.139	0.01	0.40	0.32

GE, gross energy; GEI, gross energy intake; LWG, live weight gain; EF, emission factor, kg CH_4/d; Y_{CH4}, ratio of enteric CH_4 emission per kg live weight gain; X_{CH4}, enteric CH_4 reduction efficiency of fodder crops

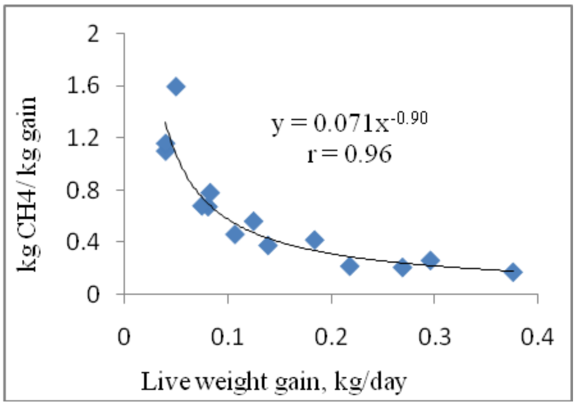

Figure 1. Relationship between live weight gain (LWG) and enteric CH_4 emission per kg gain.

3.3. Benefit to Cost Efficiency (X_{bc}) of Different Fodder Crops

The data on X_{bc} of different fodder crops are presented in Table 3. The GC_f of the fodder crops per hectare of land ranged from 228.5 US$ for UMS produced from rice straw of one hectare of land to 4013.2 US$ for the production of Moringafeed. The average cost of production of different fodder crops in a hectare of land was US$ 1899.6. Similar to cost, the market price (US$/ton DM) of different fodder crops varied and it ranged from 64.1 of local grass to 256.4 of Moringafeed with an average of 130.2 US$. The highest GR_f of different fodder crops was 8974.4 US$ for Moringafeed from a hectare of land and that of the lowest was 320.51 US$ for local grass. The average GR_f of the fodder crops was 2546.13 US$. The calculated Y_{bc} of fodder crops ranged from 1.01 of local grass to the highest of 2.24 in Moringafeed with an average of 1.32 of all the fodder crops. The calculated X_{bc} of Morimgafeed was 1.40 showing the highest efficiency of benefit to cost ratio compared to maize and other fodder, and it was the lowest for local grass and Plicatulum (0.63). The average X_{bc} of all fodder crops was 0.87. The X_{bc} of straw as a product of rice cultivation incurs only processing cost (drying, conserving etc), and when it is thoroughly mixed with urea and molasses solution, it results in 1.10 to 1.16 times benefits than that of fodder maize. Among the different fodder crops under this study German (1.06) and Moringafeed (1.40) were more cost effective than fodder maize (1.0).

Table 3. Benefit to cost efficiency of different fodder crops

Name of fodder crops	GC_f, US$/ha	US$/tonDM	GR_f, US$	Y_{bc}	X_{bc} (Fodder:Maize)
Local grass	316.24	64.10	320.51	1.01	0.63
Plicatulum	1987.18	155.30	2018.90	1.02	0.63
Napier-Bajra	2190.23	115.30	2768.81	1.26	0.79
Napier-Aurosha	2255.62	128.50	2499.84	1.11	0.69
Napier-Hybrid	2385.19	138.50	3462.50	1.45	0.91
Andropogan	2134.10	130.50	2349.00	1.10	0.69
Splendida	2108.46	130.10	2211.70	1.05	0.66
Maize	2402.30	185.70	3843.99	1.60	1.00
Sugargraze-Jumbo	1769.81	120.70	2051.90	1.16	0.72
UMS (Aman rice straw)	326.92	76.92	576.92	1.76	1.10
UMS (Aus rice straw)	228.53	76.92	423.08	1.85	1.16
Moringafeed	4013.22	256.41	8974.36	2.24	1.40
Australian Sweet Jumboo	2079.90	137.00	3205.80	1.54	0.96
Jumboo green	1641.80	156.30	2250.72	1.37	0.86
Para	2004.80	145.20	2214.30	1.10	0.69
German	2349.50	203.10	3980.76	1.69	1.06
Average	1899.61	130.16	2546.13	1.32	0.87
SD	948.13	55.28	2078.35	0.47	0.23

GC_f, annual gross cost of production of a fodder crop per ha of land; GR_f, annual gross return of the fodder crops; Y_{bc}, benefit to cost ratio of fodder crops; X_{bc}, benefit to cost efficiency of different fodder crops.

3.4. Maize Indices of Fodder Crops (M_i)

The calculated M_i based on X_{ddm}, X_{ap}, X_{CH4} and X_{bc} of fodder crops, and the RFV on the basis of D and DMI (%LW) are presented in Table 4. Considering all these factors, the M_i of Moringafeed was the highest (1.64) followed by Maize (1.00), Australian sweet jumbo (0.99) and Napier- Bajra (0.82). German, Napier-Hybrid, Napier Arusha and Andropogon had the M_i of between 0.80 and 0.50 (0.72, 0.63, 0.57 and 0.50, respectively).

Table 4. Maize index (M_i) and relative feed value (RFV) of fodder crops

Name of fodder crops	X_{ddm}	X_{ap}	X_{CH4}	X_{bc}	M_i	D%	DMI, %LW	RFV
Local grass	0.17	0.11	0.50	0.63	0.35	41.50	1.57	51
Plicatulum	0.57	0.07	0.13	0.63	0.35	55.30	1.70	73
Napier-Bajra	0.91	0.80	0.80	0.79	0.82	49.20	1.32	50
Napier-Aurosha	0.59	0.44	0.55	0.69	0.57	39.00	1.32	40
Napier-Hybrid	0.98	0.32	0.31	0.91	0.63	50.20	2.08	81
Andropogan	0.67	0.29	0.37	0.69	0.50	47.10	1.62	59
Splendida	0.60	0.20	0.27	0.66	0.43	44.50	1.45	59
Maize	1.00	1.00	1.00	1.00	1.00	59.20	2.14	98
Sugargraze-Jumbo	0.74	0.15	0.19	0.72	0.45	53.00	1.79	74
UMS (Aman rice straw)	0.23	0.05	0.18	1.10	0.39	45.50	1.92	68
UMS (Aus rice straw)	0.14	0.05	0.30	1.16	0.41	44.40	2.08	72
Moringafeed	1.83	2.12	1.21	1.40	1.64	62.70	2.81	137
Australian Sweet Jumboo	0.97	1.05	0.96	0.96	0.99	51.00	2.25	89
Jumboo green	0.63	-0.33	0.52	0.86	0.42	53.80	1.94	81
Para	0.67	-0.40	0.66	0.69	0.40	54.20	1.55	65
German	1.03	0.36	0.45	1.06	0.72	64.20	1.70	85
Average	0.73	0.39	0.52	0.87	0.63	50.93	1.85	70
SD	0.41	0.61	0.32	0.23	0.34	7.25	0.39	29

X_{ddm}, biomass production efficiency of fodder crops; X_{ap}, animal production efficiency of fodder crops; X_{CH4}, enteric methane emission reduction efficiency of different fodder crops; and X_{bc}, benefit to cost efficiency of fodder crops; Mi, maize index of fodder crops; D, digestibility; DMI, dry matter intake; RFV, relative feed value.

Next, the M_i of Sugargraze- Jumbo, Splendida, UMS (Aus rice), and Para fall between 0.49 and 0.40 (0.45, 0.43, 0.42, 0.41 and 0.40, respectively). The least M_i (below 0.40) was found in UMS (Aman rice), local grass and Plicatulum (0.39, 0.35 and 0.35, respectively). Feeding of Para grass and Jumboo green resulted in the negative X_{ap} (- 0.40 and - 0.33, respectively) due to LW loss in feeding trial which resulted in lower M_i values. The relationship between M_i and RFV of each fodder crops are presented in Figure 2. It seems that there is a significant linear (P<0.001) relationship between M_i and RFV of fodder crops and the correlation coefficient is about 0.77% (RFV= 50.888M_i+41.67; r^2 = 0.5902).

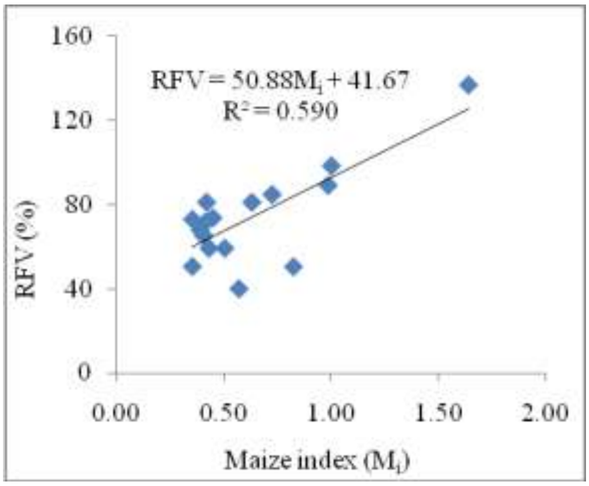

Figure 2. Relationship between Maize index (M_i) and relative feed value (RFV) of different fodder crops

3.5. Relations of Maize Index (M_i) with Different Production Parameters

The mathematical relationship between M_i and different production parameters are presented in Table 5. It shows significant linear relations of M_i with Y_{ddm} or Y_{ap} of different fodders, and they are expressed as Y_{ddm}=12580×M_i + 799 and Y_{ap}= 3384×M_i – 1356 with correlation coefficients of 0.89 and 0.96, respectively, (p<0.01, Figure 3). Similarly, the relationship of M_i with X_{CH4} of animals may be described by the equation of X_{CH4} = 1.0925×M_i- 0.3123 (r = 0.76) and the relations were found significant (P<0.01, Figure 4). A significant (p<0.01) relation of M_i with the X_{bc} of different fodders may be quantified by the equation of X_{bc} = 0.383×M_i + 0.644, (r=0.65, Figure 5). The relationship between M_i and LWG (kg/d) is found significant (p<0.001) and may be expressed as Y= 0.3077×M_i- 0.0813 (r = 0.76; Figure 6).

Table 5. Relations of M_i with different important parameters

Relations with	Equations	r, Figure no	Significance
Biomass production (kg DM/ha)	Y_{ddm} =12580M_i + 797.3	0.89, 3	P<0.01, df 15
Animal production (kg LW/ha)	Y_{ap} = 3384M_i - 1356	0.99, 3	P<0.01, df 15
CH_4 emission reduction efficiency	X_{CH4} = 1.092M_i - 0.312	0.76, 4	p<0.01, df 15
Benefit to cost efficiency	X_{bc} = 0.437M_i + 0.569	0.67, 5	P<0.01, df 15
LWG (Y; kg/d)	Y = 0.3077M_i - 0.0813	0.90, 6	P<0.01, df 15

Y_{dm}, digestible dry matter yield; Y_{ap}, live weight yield; Y_{CH4}, ratio of enteric CH_4 emission per kg live weight gain; Y_{bc}, benefit to cost ratio of fodder crops; LWG, live weight gain; r = correlation.

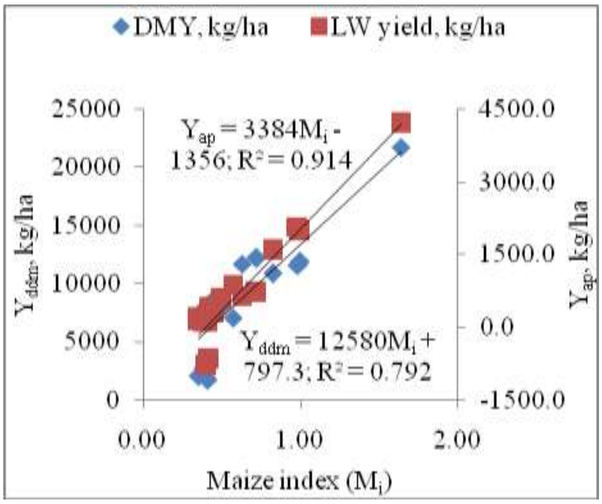

Figure 3. Relationship between maize index (M_i) and dry matter yield (Y_{ddm}; kg/ha) or live weight yield (Y_{ap}) of fodder crops (kg/ha).

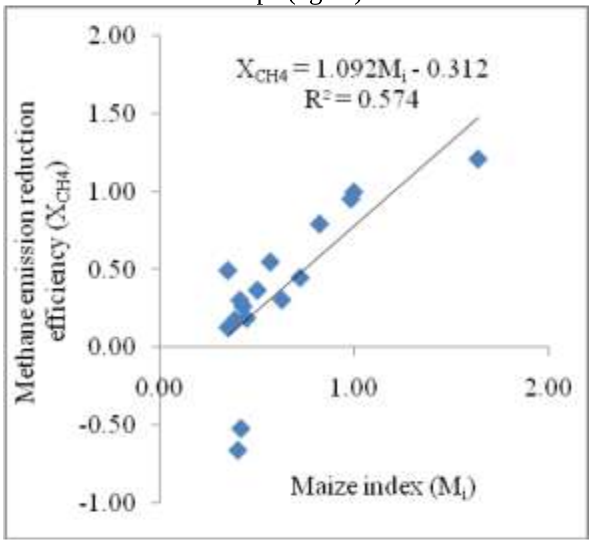

Figure 4. Relationship between maize index (M_i) and enteric methane reduction efficiency (X_{CH4}) of fodder crops

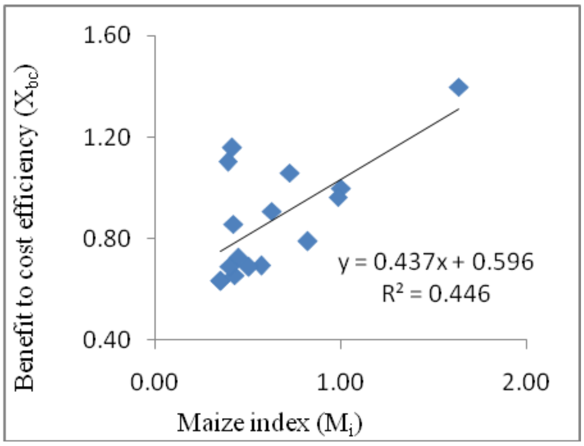

Figure 5. Relation of maize index (Mi) with the benefit to cost efficiency (X_{bc}) of fodder crops

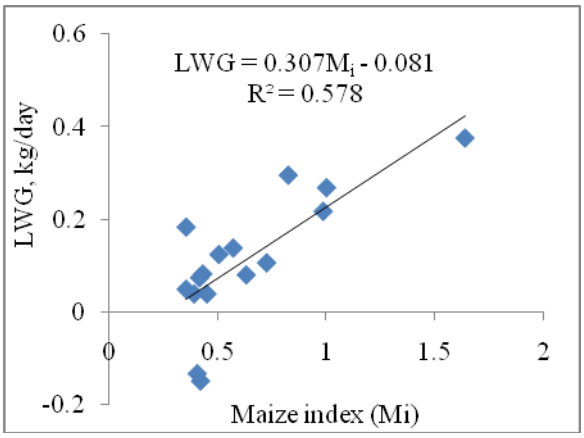

Figure 6. Relationship between maize index (Mi) and live weight gain (LWG, kg/d) of bulls

A strong relation of M_i with an increasing Y_{ddm} or Y_{ap} (Figure 3) or an increasing LWG of animals (Figure 6) and a lower emission of CH_4 in the rumen with an increasing kg LWG (Figure 1) and X_{bc} of fodder crops (Figure 5) signifies that the derived biometric system (M_i) may be considered for the ranking of available fodder crops for cost effective fodder production in the country, that may support sustainable livestock and clean air production. Thus, the Mi values derived from comparing efficiency of different fodder crops with maize may be used for the identification of quality fodder for feeding ruminant animals with a less emission of enteric methane in the climate. It may also be used for certification and releasing of fodder crops or seeds by the concerned authority for cultivation in a region. However, the ranking system may further be developed through improving database on the variations of production and productivity of biomass in different agro-climates and their feeding responses to different animals at different physiological stages.

4. CONCLUSIONS

The biometric ranking system may be followed for ranking of available fodder crops. However, the derived ranks of available fodder may vary according to the regions of a country and the physiological stages of animals. This requires further research for validation of the ranking system in different agro-climates for the animal of different physiology.

5. REFERENCES

[1] Huque KS. A performance profile of dairying in Bangladesh - programs, policies and way forwards. Bang J A Sci 2014;43(2):81-103.

[2] Ho CKM, Malcolm LR, Armstong DP and Doyle PT. A case study of changes in economic performance of an irrigated dairy farm in northern Victoria. Aus Farm Business Management J 2006;3(1):11-20. https://search.informit.com.au/documentSummary;dn=200789879892384;res=IELBUS (accessed: 15-01-2017)

[3] NRC. Nutrient requirements of dairy cattle. National Research Council (NRC), 7th revised ed. National Academic Science, Washington, DC; 2001.

[4] Shaver, RD, Undersander DJ, Schwab EC, Hoffman PC, Lauer J, Combs DK, and Hoffman PC. Evaluating forage quality for lactating dairy cows. In: Proc Inter-Mountain Nutr Conf Salt Lake City, Utah; 2002:77-94.

[5]. Yahaya MS, Takahashi J, Matsuoka Sand Kibon A. Effect of supplementary feeding of cotton seed cake on feed intake, water consumption and work output of work bulls in Borno state Nigeria. Anim Feed Sci Technol 1999;9:137-143.

[6] Kennedy, Mark, and Jennings J. Forage quality in Management Intensive Grazing in the Ozarks. Jointly published by the top of the Ozarks and the Southwest Missouri R C and D Councils. The Missouri Department of Natural Resources and the Natural Resources Conservation Service; 1997. https://www.uky.edu/Ag/Forage/ForageQuality.pdf (accessed: 15-01-2017)

[7] Boadi D and Wittenberg KM. Methane production from dairy and beef heifers fed forages differing in nutrient density using the sulphur hexafluoride (SF6) tracer gas technique. Can J Anim Sci 2002;82:201.

[8] Johnson KA and Johnson DE. Methane emissions from cattle. J Anim Sci 1995;73:2483.

[9] Ominski KH, Wittenberg KM, and Boadi D. Examination of economically and environmentally sustainable management practices in forage-based beef production systems, presented at the CCFIA Final Workshop, Winnipeg, January; 2004.

[10] Huque KS, Chowdhury MM, Das PK, Mandal, NA and Baset MA. Milk Vita –realities and reaching out to dreams of millions; The paper is presented at a regional meeting on Dairy Asia: Towards Sustainability held in Hotel Plaza Athene, Bangkok, Thailand; 2014.

[11] Huque, KS and Islam MM. Impact of Napier (*Pennisetum purpurium*) cultivation on the performance of smallholder dairy in a milk shed area of Bangladesh. Bang. J Lives Res 2006;13(1 and 2):30-38.

[12] Rohweder DA, Barnes RF and Jorgensen N. Proposed hay grading standards based on laboratory analyses for evaluating quality. J Anim Sci 1978;47:747-759.

[13] Huque KS, and Sarker NR. Feeds and feeding of livestock in Bangladesh: performance, constraints and options forward. Bang J Anim Sci 2014;43(1):1-10.

[14] Huque KS and Talukder AI. Effect of molasses supplementation of a roughage based diet on growth performances of cattle. Asian Australas J Anim Sci 1995;8(4):337-342.

[15] AOAC. Official Methods of Analysis, Central Edition. Association of Official Analytical Chemists, Wasington DC; 2004.

[16] IPCC. Intergovernmental panel on climate change (IPCC). Chapter 10: Emissions from livestock and manure management; 2006. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf (accessed: 15-01-2017)

[17] Fisher RA. *Frequency distribution of the values of the correlation coefficient in samples from an indefinitely large population.* Biometrika *1915;10(4):507–521.* doi*:*10.1093/biomet/10.4.507.

[18] Rengsirikul K, Ishii Y, Kangvansaichol K, Sripichitt P, Punsuvon V, Vaithanomsat P, Nakamanee G and Tudsri S. Biomass Yield, chemical composition and potential ethanol yields of 8 cultivars of Napiergrass (*Pennisetum purpureum* Schumach.) harvested 3-monthly in central Thailand. J S B S 2013;3:107-112. doi:10.4236/jsbs.2013.32015

[19] Roy, BK, Bashar MK, Hossain SMJ, Huque KS and Makkar HPS. Performance evaluation of *moringa oleifera* and available roughages (maize and australian sweet jumbo) on feeding values of growing BLRI Cattle Breed-1 (BCB-1) bulls. Am J Exp Agric 2016;14(1):1-9. DOI: 10.9734/AJEA/2016/29284

[20] Ribeiro GO, Teixeira AM, Velasco FO, Júnior WGF, Pereira LGR, Chaves AV, Gonçalves LC and McAllister TA. Production, nutritional quality and in vitro methane production from andropogon gayanus grass harvested at different maturities and preserved as hay or silage. Asian Australas J Anim Sci 2014;27(3):330-341. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4093266/pdf/ajas-27-3-330-5.pdf (accessed: 15-01-2017).

[21] Huque KS and Chowdhury SA. Study on supplementing effects or feeding systems of molasses and urea on methane and microbial nitrogen production in the rumen and growth performances of bulls fed a straw diet. Asian Australas J Anim Sci 1997;10(1):35-46.

[22] Tauqir NA, Sarwar M, Jabbar MA and Mahmood S. Nutritive value of jumbo grass (Sorghum bicolour sorghum sudanefe) silage in lactating Nili-Ravi buffaloes. Pakistan Vet J 2009;29(1):5-10. http://pvj.com.pk/pdf-files/29_1/5-10.pdf (accessed: 12-01-2017).

[23] Nyambati, EM, Muyekho FN, Onginjo E, and Lusweti CM. Production, characterization and nutritional quality of Napier grass (Pennisetum purpureum (Schum.)) cultivars in Western Kenya. Afr J Plant Sci 2010;4(12):496-502. http://www.academicjournals.org/ajps (accessed 22.12.2015).

[24] Rong-zhen, Z, Yi F, Hai-xia S, Min W, and Dao-wei Z. Rumen methane output and fermentation characteristics of gramineous forage and leguminous forage at differing harvest dates determined using an *in vitro* gas production technique. J Integr Agric 2015;15(2):414-423. doi：10.1016/S2095-3119(15)61036-X

[25] FAO. Greenhouse Gas Emission from the dairy sector-a life cycle assessment, Rome; 2010. http://www.fao.org/dpcrep/fao/007/y5019e00.pdf (accessed 22.12.2015).