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Phenotypic Variation of Native Chicken Populations in the South and South East Asia

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Abstract: The objective of this study was to characterize and describe native chicken populations in Bangladesh, Sri Lanka, Vietnam and Pakistan, in order to facilitate their rational development, utilization and conservation strategies. Results indicate modest variations in colours (plumage, earlobe and comb), comb types and orientation, head shape, feather patterns and shank and neck feathers, both among and within chicken breeds. Body live weights and measurements varied significantly ($p<0.05$) across countries. Body live weights were significantly different across countries, except between Bangladesh and Pakistan. Chicken breeds in Vietnam were significantly ($p<0.05$) heavier and bigger, while those in Bangladesh the smallest. Birds in Pakistan are small in size but have significantly large back lengths. Comparison within chicken breeds was conducted on the village chicken and crosses, naked neck and Vietnamese breeds. The mean body weight and other measurements varied significantly within the chicken breed groups. The mean values estimated for body weight and circumference in village chicken and crosses were significantly higher in Sri Lanka than in similar chicken breeds in Pakistan and Bangladesh. Average body weights for village chicken and crosses in the current study were 924±79.1, 1537±24.7 and 1069±24.7 g in Bangladesh, Sri Lanka and Pakistan, respectively. Among the Vietnamese chicken breeds, the Ho chicken was bigger and heavier than the rest of the breeds. The moderate variation in phenotypes among and within chicken breeds across the four study countries can be associated with geographical isolation and limited artificial selection pressure *in situ*.

Key words: Body circumference, wing length, back length, breast width, keel length, pelvis width

INTRODUCTION

Backyard poultry rearing is one of the most common features for small scale chicken farmers in the rural areas of the South and South East Asia (FAO, 2010). Native chicken populations are the main types of birds reared under this production system. They provide multiple benefits to rural farm families, particularly as food and an additional source of income. They are highly adapted to local conditions, harsh environment and the free range management systems, essential in achieving sustainability in low-input production systems (FAO, 2010; Silva, 2010; Shahjahan *et al*., 2011; Islam *et al*., 2012).

The native chicken populations in the South and South East Asia are mostly non-descript, with wide variation in sizes, shapes and plumage colours (Silva, 2010; Shahjahan *et al*., 2011; Islam *et al*., 2012). They vary in appearance according to the locality in which they have been bred. Chicken ecotypes with major alleles such as naked neck and frizzled feathered and other types such as long leg, Aseel, crown and Ho chicken *inter alia*, have been identified in this region. The diversity of these chicken populations has however decreased tremendously due to the introduction of high yielding exotic and transboundary breeds. In general, limited information on phenotypic diversity of native chicken resources is available in this region. Conducting a systemic evaluation on existing native chicken ecotypes is therefore inevitable. This study was conducted to undertake a systematic characterization and description of the native chicken populations in the South and South East Asia in order to facilitate their rational development, utilization and conservation strategies.

MATERIALS AND METHODS

Study sites: This study was conducted between 2010 and 2012 in Bangladesh, Sri Lanka, Vietnam and Pakistan. Data collection sites were selected in each

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country on the basis of the availability of the native chicken populations and their diversity. Maps showing the location of the selected sites can be accessed on the projects website http://fangrasia.org/.

In Bangladesh; Rangtia, Shalchura, Dudhnoi and Bangaon villages in Jhenaigati Upazila, Sherpur District were selected. The Jhenaigati project site is located 215 km north from capital city Dhaka. Two project sites Thirappane and Karuwalagaswewa were selected in Sri Lanka. Thirappane site is found in Anuradhapura district, located in North Central province of the country. Karuwalagaswewa site is in Puttalam district in North Western province. Both sites are located in dry zone of the country. In Thirappane site, the mean annual rainfall is 1200-1900 mm, temperature is between 28-30°C and the elevation is 89 m above sea level. Whereas the mean annual rainfall is 600-1200 mm, temperature is between 30-33°C and the elevation is 40 m above sea level in Karuwalagaswewa site.

In Vietnam, the project sites included three villages; Ho town, Lac Tho South and Lac Tho North, in Thuan Thanh District, Bac Ninh province. Bac Ninh province is located in the Red River Delta region. It is surrounded by Bac Giang to the north, Hung Yen to the south, Hai Duong to the east and Hanoi to the west. The topography is quite flat with a complex network of rivers and springs, including Cau, Duong and Thai Binh rivers. Thuan Thanh District is located on the Red River delta and it is 79 km away from Hanoi.

In Pakistan, two districts Bahawalpur and Faisalabad in Southern and Central Punjab, respectively were selected. Bahawalpuris located south of the Sutlej River and lies in the Cholistan region. Three villages were selected from this district which included Fateh 78, Fateh 76 and Murad 147 situated in Tehsil Hasilpur. Faisalabad is located in the Faisalabad district. This district has an area of 5, 856 km^2 with the river Ravi flowing on the Eastern and the Chenab on the Western boundaries. Three villages, Waseeran, Dalowal and Balochwala were selected as the study sites.

Since this was part of an on-going study, only the households surveyed in the baseline survey were considered. In addition, total sampling of chicken owned by households rather than random sampling from their flocks was done. This allowed for adequate evaluation of individual chicken and flock genetic structure and provided ample information for feedback to the households/site.

Data source: A field experiment was conducted on 2049 chicken in four countries as follows; 155 (146 females and 9 males) in Bangladesh, 818 (654 females and 164 males) in Sri Lanka, 311 (163 females and 148 males) in Vietnam and 765 (582 females and 183 males) in Pakistan (Table 1). The study comprised of 3 and 8 chicken breeds in, respectively, Bangladesh and Sri Lanka. In Vietnam and Pakistan, 10 chicken breeds were sampled in each country.

Table 1: Selected chicken ecotypes in Bangladesh, Sri Lanka, Vietnam and Pakistan

	Breed/Variety	No. (N)	Old breed code country	New breed code
Bangladesh	Gharsila Murgi	4	3	27
(N = 155)	Deshi Murgi	137	4	
	Tupiwala Murgi	14	6	
Sri Lanka	Normal Village chicken-red, black, brown, white (*Gam kukullu*)	582	1	37
(N = 818)	Village chicken crossed with commercial chicken	22	6	
	Naked neck (*Peda kapapu*)	138	2	32
	Long leg (*Pora kukullu*)	43	3	33
	Crown (*Konda kikili*)	6	4	34
	Village chicken crossed with jungle fowl	-	5	-
	Chinese chicken (may be a cross with Indian breed)	-	7	-
	Others (Commercial layers and Frizzled feathered chicken)	27	8	38
Vietnam	Ho (also called To chicken)	102	1	41
(N = 311)	Ri (also called Ta chicken, plumage colour varies)	9	2	42
	Dong Tao	6	3	43
	Choi (fighting chicken)	-	4	-
	Tre (boombu)	7	5	45
	Mia	6	6	46
	H'mong (black meat, plumage colours in brown, black and white)	-	7	-
	Sasso	-	8	-
	Ac (black, 5 toe chicken)	-	9	-
	Others (crosses)	181	10	50
Pakistan	Aseel (fighting)	95	1	1
(N = 765)	Naked Neck	24	2	2
	Fayoumi (less exotic)	29	3	3
	Rhode Island Red (RIR-less exotic)	87	4	-
	White leghorn (exotic)	3	8	-
	Desi: Fayoumi x RIR	20	5	17
	Desi: less exotic x Aseel	67	6	
	Desi: less exotic x unknown	312	7	
	Desi	89	11	
	Desi Aseel/Dogli	39	12	

The native chicken populations in the four countries were sampled using qualitative and quantitative traits following the FAO (2012) standard descriptor. The qualitative traits identified for morphological description of chicken were colour (plumage, comb and earlobe), tail, comb types and orientation, head shape, feather patterns and shank and neck feathers.

The quantitative traits (body morphometric measurements) were taken once on chicken aged 4 months and above. Individual chicken were weighed using a scale and the body live weight recorded. Other linear measurements and photography (front, rare and side) were taken on chicken, placed on all legs, on an even surface. The body measurements (Fig. 1) included: *Body circumference* is measured with the tape at the anterior end of the keel bone. The tape is passed under the wings and anterior to the legs; Wing Length taken from the shoulder joint to the extremity of the terminal phalanx, digit III; Back length when the chicken is standing, the neck curves so that the neck is almost perpendicular to the back. The back is measured from the nadir of the curve to the base of the tail; Breast width the anterior end of the keel is measured using a calliper while the chicken is held on its back; Keel length is measured with the tape as the chicken is held on its back; Pelvis width is measured when the chicken is standing. The callipers rested on the back and the distance between the outer edges of the thighs measured; Drum length the distance from the shank joint (s); Shank circumference of the "drum stick" taken at the uppermost part of the shank and Shank length distance from the upper most shank joint to the toe joints.

Data analysis: Chicken data was analyzed using several statistical procedures of SAS (SAS, 2003). The descriptive and least square means (LSM) were done separately for the four countries. Data from chicken breeds with similar conformation and breed names in each country were pooled together during the analyses. Village chicken and crosses were categorized into; 27 (code 3, 4 and 6 in Bangladesh), 37 (code 1 and 6 in Sri Lanka) and 17 (code 5, 6, 7, 11 and 12 in Pakistan). Pure commercial chicken breeds were excluded in the analysis i.e., part of the data for breed codes 8 in Sri Lanka and 4 and 8 in Pakistan. The number of chicken used in the final data analysis remained the same for Bangladesh and Vietnam, but reduced to 797 (635 females and 162 males) in Sri Lanka and 676 (534 females and 142 males) in Pakistan.

RESULTS

Phenotypic (colour) variations in the native chicken populations

Plumage colour: The plumage colour variations for the different chicken ecotypes in the four study countries are shown in Table 2a. The greyish mixture (18.5%), black (17%), multicolour (15.9%) and black other (13.9%) were the most predominant colours of the native chicken populations in the four countries.

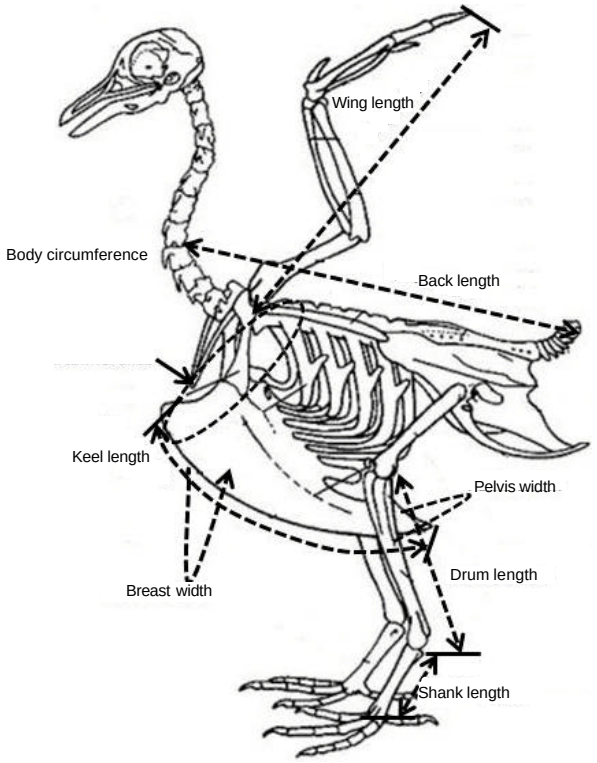

Fig. 1: Linear body measurements taken for native chicken breeds in the four study countries

Black plumage colour was predominantly reported across countries (Bangladesh, Sri Lanka and Pakistan) with the village chicken and crosses. The other major colours recorded were green and greyish mixture in Pakistan; multicolour in Bangladesh and Sri Lanka and black other in Sri Lanka.

The green (50%) and black and black other (each 26.1%) were the most common colours documented for the naked neck ecotype in Pakistan and Sri Lanka, respectively. Considerable number of chicken in this group also had greyish mixture (37.5%) and multicolour (19.6%) colour variations.

The black other plumage colour was predominant in the main Vietnamese breeds, the Ho (36.3%) and crosses (27.1%). In addition, a considerable number of these chicken breeds had yellow (16.7 and 26%) and white other (16.7 and 11.6%) colour variations.

For rest of the chicken breed groups, green (36.8%) was dominant in Aseel, greyish mixture (65.5%) in Fayoumi, Long leg were mainly multicolour (55.8%) and Frizzled feathered chicken were either white, black or black other (each 20%).

Table 2a: Phenotypic (plumage colour) variation of different chicken breeds in Bangladesh, Sri Lanka, Pakistan and Vietnam

Plumage colour	Aseel	Naked neck		-------- Village chicken -------- --------- and crosses ----------			Fayoumi	Long leg	Frizzled feathered	Ho	Ri	Dong Tao	Tre	Mia	Vietnamese Crosses	Overall mean
	1	2	32	17	37	27	3	33	38	41	42	43	45	46	50	
Black	25.3	12.5	26.1	11.9	26.0	15.5	17.2	2.3	20.0	1.0	11.1	16.7	14.3	83.3	3.3	17.0
White	2.1		5.1	4.7	7.5	3.9		7.0	20.0	7.8			28.6		3.9	5.6
Yellow	3.2			2.7	0.3	3.2	10.3	2.3		16.7	11.1	16.7			26.0	4.9
Green	36.8	50.0		35.0			6.9									12.1
Red				0.6		5.8									0.6	0.7
Greyish mixture	32.6	37.5	5.8	43.4	4.0	2.6	65.5		13.3	6.9	33.3		28.6	16.7	10.5	18.5
Multicolour			19.6	1.1	25.3	49.7		55.8	20.0	4.9			28.6		6.6	15.9
Black other[a]			26.1		19.3	9.0		27.9	6.7	36.3	22.2	33.3			27.1	13.9
Red other[a]			3.6	0.2	3.3	9.7				1.0					0.6	2.2
White other[a]			1.5	0.2	1.3	0.7		4.7		16.7	22.2				11.6	2.8
Yellow other[a]				0.2						8.8		33.3			9.9	1.6
Brown			12.3		13.0				20.0							5.1

[a]Main colour is either black, red, white or yellow, with mixture of other colours

Table 2b: Phenotypic (comb and earlobe colour) variation of different chicken breeds in Bangladesh, Sri Lanka, Pakistan and Vietnam

Parameter	Color	Aseel	Naked neck		-------- Village chicken -------- --------- and crosses ----------			Fayoumi	Long leg	Frizzled feathered	Ho	Ri	Dong Tao	Tre	Mia	Vietnamese Crosses	Overall mean
		1	2	32	17	37	27	3	33	38	41	42	43	45	46	50	
Comb	Black	6.3	4.2	2.2	3.4		1.3	6.9								1.1	2.1
	White	1.1			0.2		0.5										0.3
	Green				0.8												0.2
	Red			87.0		98.7	86.7		69.8	93.3	100.0	100.0	100.0	100.0	100.0	98.9	59.2
	Multicolour			5.8	0.2	0.7	3.0		11.6	6.7							1.8
	Red other[a]	92.6	95.8		95.3			93.1									33.1
	White other[a]			2.2		0.7	4.0		9.3								1.7
	Pink			2.2	0.2		3.0		4.7								1.2
	Orange			0.7			1.0		4.7								0.5
	Purple						0.3										0.1
	No comb						0.2										0.1
Earlobe	Black		8.3	2.9	1.3	0.7	0.2									1.7	0.9
	White	13.7	12.5	4.4	25.6	27.7	6.5	27.6			4.9	33.3		42.9		15.5	14.8
	Yellow			0.7			2.3		4.7								0.9
	Green		4.2		0.2		0.2	6.9									0.3
	Red			55.1		11.6	61.7		53.5	100.0	95.1	66.7	100.0	57.1	100.0	82.9	39.8
	Multicolour			15.9					20.9								4.9
	Black other[a]			2.9			10.5										0.2
	Red other[a]	71.6	37.5	0.7	43.8	0.7	0.2	41.4									16.7
	White other[a]			16.7		56.8	15.3		16.3								10.9
	Pink	14.7	37.5	0.7	28.8	2.6	2.2	24.1	2.3								10.4
	Orange						0.8		2.3								0.3
	Purple						0.2										0.1

[a]Main colour is either red, white or black, with mixture of other colours

Comb colour: The comb colours for chicken ecotypes in Pakistan and other study countries were predominantly red other and red, respectively. The overall mean indicates 33.1% (red other) and 59.2% (Red) colour variations. About 95.3, 98.7 and 86.7% of village chicken and crosses had red other and red colour variations, respectively. Similar trend was observed for comb colours in the naked neck, Vietnamese and other chicken breeds.

Earlobe colour: The overall means indicate that about 39.8, 66.7 and 44.8% of all the chicken ecotypes have red, red other and white ear lobe colours receptively. White other (10.9%) and pink (10.4%) collared ear lobes were also common.

The village chicken and crosses had varied earlobe colours across the three countries. About 43.8%, (red other), 56.8% (white other) and 61.79 (red), receptively, were reported in Pakistan, Bangladesh and Sri Lanka.

The naked neck breeds of chicken also had different earlobe colour variations across countries. The red other (37.7%) and pink (37.5%) collared earlobes were common in Pakistan whereas red (55.1%) and white other (16.7%) were common among the naked neck chicken breeds in Sri Lanka.

The Aseel, Fayoumi, Long leg and Frizzled feathered chicken ecotypes had predominantly red other (71.6%), red other (41.4%), red (53.5%) and red (100%) earlobe colours, respectively. The earlobe colours for the Vietnamese chicken breeds were predominantly red and a small number of these breeds had white and black earlobes.

Morphological characteristics for different chicken populations

Tail: The results indicate that over 90% of all the chicken ecotypes in the four study countries had tails, except the Dong Tao chicken breed in Vietnam. The presence and absence of a tail was reported in about 66.7% and 33.3% of Dong Tao chicken populations, respectively. However, this did not influence the overall mean of all chicken ecotypes with tails estimated at 97.5% of the total chicken population sampled.

Comb types and orientation: The overall mean indicate that about 55.8 and 25.2% of all the chicken ecotypes reported in all the four study countries had single and pea comb types, respectively. A considerable percentage of chicken however had strawberry (9.9%) and rose (5.4%) comb types. Most village chicken and crosses, naked neck, other chicken breeds (e.g. Fayoumi, Long leg, Frizzled feathered) and Ri have a single type of comb. Aseel, Dong Tao and Mia have predominantly pea comb type. Majority of the Ho chicken and Vietnamese chicken crosses have strawberry comb types.

The result on comb orientation was only available for Pakistani chicken breeds. The upright and tilted types of comb orientation were the most predominant, with about 83 and 16.9%, respectively, of all the chicken breeds evaluated.

Head shape: Majority of the chicken ecotypes in all the study countries had plain head shape. The overall means indicates that about 97 and 2.9% of all the chicken populations had plain and crested heads, respectively. The village chicken and crosses had the largest number of chicken with crested head shape in the countries.

Feather pattern: The feather patterns recorded in most of the chicken ecotypes was not definite. About 90.8, 4.8 and 2.5% of the chicken ecotypes had feather patterns that were not definite, other (combination of different feather patterns) and lacing, respectively.

Shank and neck feathers: Majority (98.9%) of all the chicken breeds in this study did not have shank feathers. Shank feathers were reported in about 2.2 and 2.0% in the Ho and Vietnamese chicken crosses, receptively.

Apart from the naked neck breeds which had 75 and 93.5% of neck fathers absent, over 90% of the rest of the chicken breeds had neck feathers. The overall means indicate that about 9.7 and 90.3% of all the chicken ecotypes do not and have neck feathers, receptively.

Body linear measurements

Comparison of chicken breeds across countries: Table 4 presents the least square means (LSM) for the different trait measurements taken in native chicken populations of Bangladesh, Sri Lanka, Vietnam and Pakistan. Body weight (g) measurements varied significantly ($p<0.05$) across countries, except between Bangladesh and Pakistan. The average body weight estimates were highest in Vietnam (2802±28), followed by Sri Lanka (1531±22), Pakistan (1025±24) and Bangladesh (924±86). A similar trend in body weight estimates was also observed between male and female chicken in all the countries. Both male and female chicken in Vietnam were heavier than chicken in the rest of the countries.

The body and shank circumference measurements varied significantly across countries ($p<0.05$). The highest body circumference values were estimated in Sri Lanka (328±1.8), whereas the shank circumference values estimated was highest in Vietnam (143±1.0). Chicken breeds in Bangladesh had the lowest values estimated for both body (215±7.2) and shank circumference (46±3.0).

The mean estimates of wing, back, keel, drum and shank length varied across countries. Apart from back length, all the values estimated were highest in chicken

Table 3: Morphological characteristics of different chicken breeds in Bangladesh, Sri Lanka, Pakistan and Vietnam

Parameter	Variable	Aseel	Naked neck		Village chicken and crosses			Fayoumi	Long leg	Frizzled feathered	Ho	Ri	Dong Tao	Tre	Mia	Vietnamese Crosses	Overall mean
		1	2	32	17	37	27	3	33	38	41	42	43	45	46	50	
Tail	Absent			4.4	0.6		4.0		2.3	6.7	5.9		33.3			3.3	2.5
	Present	100.0	100.0	95.7	99.4	100.0	96.0	100.0	97.7	93.3	94.1	100.0	66.7	100.0	100.0	96.7	97.5
Comb	Single	3.2	87.5	69.6	58.1	99.4	62.7	89.7	39.5	66.7	1.0	66.7		71.4		33.2	55.8
type	Pea	92.6	12.5	18.1	38.8	0.7	12.5	10.3	30.2	6.7	13.7	33.3	83.3	14.3	100.0	24.9	25.2
	Walnut	2.1			0.8												0.3
	Rose	1.1		2.2	1.7		14.4		9.3	13.3							5.4
	V-shaped																
	Strawberry			2.9	0.4		3.2		9.3	6.7	82.4		16.7	14.3		41.4	9.9
	Buttercup			3.6			1.2			6.7							0.7
	Cushion			3.6			6.0		11.6		2.9					0.6	2.6
	Other	1.1			0.2												0.1
Comb	Upright	95.8	58.3		82.9			62.1									83.0
orientation	Tilted	3.2	41.7		17.1			37.9									16.9
	Other[a]	1.1															0.2
Head	Plain	99.0	100.0	96.4	98.7	95.5	94.5	100.0	95.4	100.0	100.0	100.0	100.0	100.0	100.0	99.4	97.1
shape	Crest	1.1		3.6	1.3	4.5	5.5		4.7							0.6	2.9
Feather	Not definite	68.4	83.3	100.0	76.7	99.4	98.7	75.9	100.0	73.3	99.0	100.0	100.0	100.0	100.0	99.5	90.8
pattern	Lacing	3.2	8.3		5.5	0.7	1.3	10.3			1.0					0.6	2.5
	Frizzled									26.7							0.2
	Barring	1.1			0.2			6.9									0.2
	Mottling/ Spangling	7.4			3.0												1.2
	Pencilling	2.1			1.0												0.4
	Other[b]	17.9	8.3		13.6			6.9									4.8
Shank	Absent	99.0	100.0	99.3	98.9	99.4	98.8	100.0	100.0	100.0	98.0	100.0	100.0	100.0	100.0	97.8	98.9
feathers	Present	1.1		0.7	1.1	0.7	1.2				2.0					2.2	1.1
Neck	Absent		75.0	93.5	1.3	1.9	3.3		2.3	6.7	3.9					2.8	9.7
feathers	Present	100.0	25.0	6.5	98.7	98.1	96.7	100.0	97.7	93.3	96.1	100.0	100.0	100.0	100.0	97.2	90.3

[a]Not belong to Upright or tilted orientations

[b]Combination of the listed feather patterns

Table 4: Least Square Means (LSM) and standard errors of body morphometric measurements for chicken ecotypes in Bangladesh, Sri Lanka, Vietnam and Pakistan

Trait	Sex	Bangladesh (N = 155)	Sri Lanka (N = 797)	Vietnam (311)	Pakistan (N = 676)
Body weight (g)	F	967±42	1306±20	2428±39	1146±22
	M	881±167	1757±39	3178±41	905±42
	Over.	924±86^{a}	1531±22^{b}	2802±28^{c}	1025±24^{a}
Body circumference (mm)	F	221±3.5	308±1.7	307±3.3	253±1.8
	M	209±14.0	349±3.3	320±3.4	254±3.5
	Over.	215±7.2^{a}	328±1.8^{b}	313±2.4^{c}	254±2.0^{d}
Wing length (mm)	F	153±1.8	148±0.9	215±1.7	167±1.0
	M	174±7.4	168±1.7	239±1.8	166±1.9
	Over.	164±3.8^{ab}	158±1.0^{b}	227±1.3^{c}	166±1.1^{a}
Back length (mm)	F	153±3.8	263±1.8	222±3.6	578±2.0
	M	172±15.3	296±3.6	241±3.8	576±3.8
	Over.	163±7.9^{a}	280±2.0^{b}	231±2.6^{c}	577±2.2^{d}
Breast width (mm)	F	93±1.2	76±0.6	94±1.1	77±0.6
	M	89±4.7	84±1.1	107±1.2	77±1.2
	Over.	91±2.4^{a}	80±0.6^{b}	100±0.8^{c}	77±0.7^{d}
Keel length (mm)	F	87±1.7	100±0.8	139±1.7	96±0.9
	M	86±7.0	115±1.7	153±1.7	96±1.8
	Over.	86±3.6^{a}	108±0.9^{b}	146±1.2^{c}	96±1.0^{a}
Pelvis width (mm)	F	26±0.7	21±0.3	44±0.7	21±0.4
	M	18±2.8	10±0.7	32±0.7	20±0.7
	Over.	22±1.4^{a}	15±0.4^{b}	38±0.5^{c}	21±0.4^{a}
Drum length (mm)	F	60±1.6	128±0.8	166±1.5	131±0.8
	M	69±6.4	151±1.5	184±1.6	120±1.6
	Over.	65±3.3^{a}	139±0.9^{b}	175±1.1^{c}	125±0.9^{d}
Shank circumference (mm)	F	43±1.4	66±0.7	134±1.4	97±0.8
	M	48±5.8	78±1.4	152±1.4	87±1.5
	Over.	46±3.0^{a}	72±0.8^{b}	143±1.0^{c}	92±0.8^{d}
Shank length (mm)	F	-	-	-	88±0.5
	M	-	-	-	81±1.0
	Over.	-	-	-	85±0.6

^{abcd}Means with a different superscript in a row are significantly different ($p<0.05$) Adjusted p-values (Tukey-Kramer)

breeds of Vietnam. In addition, all the values estimated were lowest for chicken breeds in Bangladesh, except for wing length. The value estimated for back length (577±2.2) was unusually high in Pakistan, about two-fold of those estimated in other countries.

The mean values estimated for breast (100±0.8) and pelvis (38±0.5) widths in the chicken breeds of Vietnam were significantly ($p<0.05$) higher than for the chicken breeds in the other countries (Table 4). The breast width was lowest for chicken breeds in Pakistan while value estimates for pelvis width was lowest in the chicken breeds of Sri Lanka.

Comparison between chicken breeds: Table 5 presents the mean trait measurements taken in closely related (pooled) native chicken populations of Bangladesh, Sri Lanka, Vietnam and Pakistan. Comparison of the different body measurements between chicken breeds indicate that the Ho and Vietnamese chicken crosses were significantly ($p<0.05$) heavier and bigger in most traits than the rest of the chicken breeds, except for back length. The highest values for body weight (g) were estimated in Ho (3347±46.3) and Vietnamese (2661±34.3) chicken crosses, whereas the Fayoumi (1025±124.0) and Aseel (793±54.4) had the lowest weights. On the contrary, values estimated for back length were highest in Aseel (624±5.2) and Fayoumi (578±11.8) and lowest in the Ho (241±4.4) and Vietnamese chicken crosses (231±3.3). In the remaining trait measurements, the body circumference (252±10.7), breast width (76±3.7) and Keel length (96±5.4) were lowest in Fayoumi. The drum length was lowest in Aseel (113±2.1), wing length in the Village chicken and crosses (159±0.8), pelvis width in the Long leg chicken (10±1.3) and shank circumference in Frizzled feathered chicken (74±4.8).

Comparison within chicken breeds: Village chicken and crosses: Table 6a presents the mean trait measurements taken in closely related (pooled) native chicken populations of Bangladesh, Sri Lanka and Pakistan. Comparison of village chicken breeds and crosses indicate that chicken breeds in Sri Lanka were significantly ($p<0.05$) heavier and bigger than their counterparts in Pakistan and Bangladesh. The mean body weight (g) and circumference (mm) estimates were 1537±24.7 and 329±2.1 (Sri Lanka), 1069±24.7 and 245±2.1 (Pakistan) and 924±79.1 and 215±6.8 (Bangladesh), respectively. Similarly, the keel and drum length estimates in the village chicken and crosses of Sri Lanka were significantly longer than those estimated for closely related chicken breeds in Pakistan and Bangladesh.

Table 5: Least Square Means (LSM) and standard errors of body morphometric measurements for closely related (pooled) native chicken breeds in the four countries

Trait	Sex	Aseel (N = 95)	Naked neck (N = 162)	Fayoumi (N = 29)	Village chicken and crosses (N = 1284)	Long leg (N = 43)	Frizzled feathered (N = 15)	Ho (N = 102)	Vietnamese Crosses (N = 181)
Body weight (g)	F	946±54.7	1241±43.3	1375±92.1	1201±15.2	1293±111.7	2097±138.9	2840±59.5	2320±49.1
	M	641±94.0	1580±89.1	676±230.3	1345±33.1	1670±90.3	2110±230.3	3855±71.1	3001±47.8
	Over.	793±54.4^{a}	1410±49.5^{b}	1025±124.0^{ab}	1273±18.2^{b}	1482±71.8^{b}	2104±134.5^{c}	3347±46.3^{d}	2661±34.3^{e}
Body circumference (mm)	F	285±4.7	293±4.5	243±7.9	273±1.6	298±9.6	359±12.0	322±5.1	307±4.2
	M	303±8.1	341±9.2	260±19.9	291±3.4	342±7.8	371±19.9	351±6.1	310±4.1
	Over.	294±4.7^{abc}	317±5.1^{bd}	252±10.7^{c}	282±1.9^{c}	320±6.2^{abd}	365±11.6^{d}	337±4.0^{d}	309±3.0^{ab}
Wing length (mm)	F	181±2.5	152±1.9	163±4.2	155±0.7	151±5.1	153±6.3	219±2.7	219±2.2
	M	184±4.3	171±4.0	170±10.5	164±1.5	171±4.1	194±10.5	251±3.2	237±2.2
	Over.	183±2.5^{a}	162±2.2^{b}	166±5.7^{ab}	159±0.8^{b}	161±3.3^{b}	173±6.1^{ab}	235±2.1^{c}	228±1.6^{c}
Back length (mm)	F	623±5.2	300±12.5	568±8.8	370±4.4	280±10.7	282±13.2	227±5.7	223±4.7
	M	625±9.0	329±25.8	588±22.0	425±9.6	284±8.6	311±22.0	255±6.8	238±4.6
	Over.	624±5.2^{a}	315±14.3^{b}	578±11.8^{a}	397±5.3^{c}	282±6.9^{bd}	296±12.8^{bcd}	241±4.4^{d}	231±3.3^{d}
Breast width (mm)	F	87±1.6	76±1.3	74±2.8	78±0.5	76±3.4	85±4.2	94±1.8	95±1.5
	M	89±2.8	82±2.6	78±6.9	80±1.0	82±2.7	84±6.9	107±2.1	109±1.4
	Over.	88±1.6^{a}	79±1.5^{b}	76±3.7^{ab}	79±0.5^{b}	79±2.2^{b}	85±4.0^{ab}	100±1.4^{c}	102±1.0^{c}
Keel length (mm)	F	107±2.4	98±1.9	95±4.0	96±0.7	103±4.8	110±6.0	144±2.6	132±2.1
	M	110±4.1	110±3.8	98±9.9	103±1.4	114±3.9	111±9.9	167±3.1	149±2.1
	Over.	108±2.3^{a}	104±2.1^{ab}	96±5.4^{ab}	100±0.8^{b}	108±3.1^{ab}	110±5.8^{ab}	155±2.0^{c}	141±1.5^{d}
Pelvis width (mm)	F	26±1.0	21±0.7	20±1.6	21±0.3	14±2.0	29±2.5	44±1.1	45±0.9
	M	25±1.7	14±1.5	23±4.1	14±0.6	7±1.6	14±4.1	35±1.3	30±0.8
	Over.	25±1.0^{a}	17±0.8^{b}	21±2.2^{ab}	18±0.3^{b}	10±1.3^{c}	21±2.4^{ab}	40±0.8^{d}	37±0.6^{d}
Drum length (mm)	F	123±2.1	129±2.3	139±3.6	120±0.8	135±4.4	143±5.5	178±2.3	163±1.9
	M	104±3.7	146±4.8	115±9.1	134±1.8	152±3.6	149±9.1	202±2.8	179±1.9
	Over.	113±2.1^{a}	137±2.6^{b}	127±4.9^{abc}	127±1.0^{c}	144±2.8^{b}	146±5.3^{bc}	190±1.8^{d}	171±1.3^{e}
Shank circumference (mm)	F	87±1.9	70±2.0	104±3.3	75±0.7	73±4.0	72±4.9	142±2.1	134±1.7
	M	75±3.3	80±4.1	78±8.2	82±1.5	80±3.2	76±8.2	167±2.5	147±1.7
	Over.	81±1.9^{a}	75±2.3^{a}	91±4.4^{a}	79±0.8^{a}	76±2.6^{a}	74±4.8^{a}	154±1.7^{b}	141±1.2^{c}
Shank length (mm)	F	84±1.4	87±2.6	92±2.3	88±0.6	-	-	-	-
	M	74±2.4	83±5.9	75±5.9	83±1.1	-	-	-	-
	Over.	79±1.4^{a}	85±3.2^{ab}	84±3.2^{ab}	86±0.6^{b}			-	-

^{abcde}Means with a different superscript in a row are significantly different ($p<0.05$) Adjusted p-values (Tukey-Kramer)

Naked neck (codes 2 and 32) and Village chicken and crosses (codes 17, 27 and 37)

Comparison of village chicken and crosses based on the other body measurements indicate that back length and shank circumference estimates were highest in Pakistan while values estimated for wing length and breast and pelvis width were highest in Bangladesh.

Naked neck: The naked neck breeds of chicken were reported only in Pakistan and Sri Lanka (Table 6a). The naked neck chicken breed in Sri Lanka was significantly different and superior in terms of body weight and circumference than the Pakistani breeds. The body weight (g) and circumference (mm) estimates were, respectively, 1472±49.4 and 325±4.3 in Sri Lanka and 1000±126.1 and 272±10.9 in Pakistan. The keel and drum lengths were also longer in Naked neck chicken in Sri Lanka than in Pakistan but not significantly different. The rest of the trait measurements were higher in naked neck breeds of Pakistan than Sri Lanka. However, only the back length and shank circumference estimates in naked neck breeds were significantly different between the two countries.

Vietnamese chicken breeds: Table 6b presents the mean trait measurements taken in the native chicken populations of Vietnam. Majority of the chicken breeds in the selected study sites in Vietnam were either Ho or Vietnamese chicken crosses (Table 1). The Ho chicken was significantly ($p<0.05$) heavier and bigger than most of the chicken breeds in Vietnam. The values estimated for body weight (3347±46.3), body circumference (337±4.0), wing length (235±2.1), drum length (190±1.8) and shank circumference (154±1.7) were highest in this chicken breed. In contrast, the highest values for back length (243±17.9) and pelvis width (48±3.3) were estimated in Dong Tao, Keel length (172±7.6) in Tre and breast width (102±1.0) in Vietnamese crosses. In addition, the Tre chicken had relatively lower body weight (646±172.7 g) than the rest of the Vietnamese chicken breeds.

DISCUSSION

The findings of this study indicate modest variations in colours (plumage, earlobe and comb), comb types and orientation, head shape, feather patterns and shank and neck feathers, both among and within chicken breeds. These variations in the native chicken populations across the four study countries can be associated with geographical isolation and limited artificial selection pressure *in situ*. These findings are in agreement with previous studies in Africa (Melesse and Negesse, 2011; Halima *et al*., 2007; Badubi *et al*., 2006; Mcainsh *et al*., 2004; Missohou *et al*., 1998) and Asia (Bhuiyan *et al*., 2005; Ahmed and Ali, 2007; FAO, 2008; Faruque *et al*., 2010; Islam *et al*., 2012). Indigenous chickens anatomically have diverse plumage colours that aid for camouflage against predators (Duguma, 2006). However, plumage colours have become an important component in breeding influencing both the market demand and supply chains of local chicken breeds in developing countries (Dana *et al*., 2010; Bett *et al*., 2011; Bett *et al*., 2012). In addition, plumage colour of indigenous chicken in Bangladesh was reported to have a significant effect on egg production (Shahjahan *et al*., 2011).

The majority of native chicken breeds in these countries exhibited important characters associated with adaptability to widespread tropical environments. These include important alleles responsible for naked neck, frizzled feathered, pea comb, Long legs and small body weight (Islam and Nishibori, 2009; Sahota *et al*., 2003; Shahjahan *et al*., 2011). Some of these alleles have been identified with better heat dissipation, less feed requirements and productivity (Islam and Nishibori, 2009; Sahota *et al*., 2003; Shahjahan *et al*., 2011), which can be crucial in the development of appropriate chicken genotypes for tropical production environments.

Comparisons of the average body linear measurements across countries indicate that the native Vietnamese chicken populations were significantly bigger and heavier than chicken in the rest of the countries. Most of the body measurements and weights were lowest in Bangladesh followed by Pakistan and Sri Lanka in that order. In agreement with the current study, average mature body weights of about 1000 to 1300 g were reported in the village chicken breeds (Deshi) of Bangladesh (Bhuiyan *et al*., 2005), 1221-1591 g in Sri Lanka (Sanjeewa *et al*., 2011) and 600 to 4000 g in Vietnamese breeds (FAO, 2008),

Between breed comparisons of chicken in the four study countries show that the Ho and Vietnamese chicken crosses were heavier and bigger in most trait measurements than the rest of the chicken breeds. Generally, the Ho, Dong Tao and Choi chicken breeds in Vietnam have compact body size, long legs and heavy in size compared to the rest of the breeds in this study. Body weight and measurements for the different chicken breeds in Bangladesh, Sri Lanka and Pakistan compare well with those reported in the literature (Wickramaratne *et al*., 1993; Iqbal and Pampori, 2008; Islam and Nishibori, 2009; Sahota *et al*., 2003; Sanjeewa *et al*., 2011).

Comparison within chicken breeds was conducted only on the village chicken and crosses, naked neck and Vietnamese breeds. The mean body weight and other measurements varied significantly within the chicken breed groups. The mean values estimated for body weight and circumference in village chicken and crosses were significantly higher in Sri Lanka than in similar chicken breeds in Pakistan and Bangladesh. Performance of the village chicken breeds reported in Sri Lanka and Bangladesh (Bhuiyan *et al*., 2005; Sanjeewa *et al*., 2011) are in agreement with the findings of this

Table 6a: Least Square Means (LSM) and standard errors of body morphometric measurements for closely related (pooled) native chicken breeds in Bangladesh, Sri Lanka and Pakistan

		---------- Naked neck ----------		---------- Village chicken and crosses ----------		
		2	32	17	27	37
Trait	Sex	(N = 24)	(N = 138)	(N = 528)	(N = 155)	(N = 601)
Body weight (g)	F	1165±103.0	1255±43.7	1165±22.5	967±38.1	1300±20.7
	M	836±230.3	1690±88.6	973±43.9	881±153.5	1774±44.9
	Over.	1000±126.1^{a}	1472±49.4^{b}	1069±24.7^{a}	924±79.1^{a}	1537±24.7^{b}
Body circumference (mm)	F	250±8.9	301±3.8	248±1.9	221±3.3	308±1.8
	M	295±19.9	348±7.6	242±3.8	209±13.2	350±3.9
	Over.	272±10.9^{a}	325±4.3^{c}	245±2.1^{a}	215±6.8^{b}	329±2.1^{c}
Wing length (mm)	F	164±4.7	150±2.0	164±1.0	153±1.7	147±0.9
	M	188±10.5	169±4.1	162±2.0	174±7.0	166±2.1
	Over.	176±5.8^{ab}	160±2.3^{ab}	163±1.1^{a}	164±3.6^{ab}	157±1.1^{b}
Back length (mm)	F	571±9.8	251±4.2	571±2.1	153±3.6	264±2.0
	M	633±22.0	284±8.5	563±4.2	172±14.6	302±4.3
	Over.	602±12.0^{a}	268±4.7^{b}	567±2.4^{a}	162±7.5^{c}	283±2.4^{b}
Breast width (mm)	F	76±3.1	76±1.3	75±0.7	93±1.1	76±0.6
	M	88±6.9	81±2.7	74±1.3	89±4.6	86±1.3
	Over.	82±3.8^{abc}	78±1.5^{ac}	75±0.7^{a}	91±2.4^{b}	81±0.7^{c}
Keel length (mm)	F	95±4.4	99±1.9	94±1.0	87±1.6	100±0.9
	M	110±9.9	110±3.8	92±1.9	86±6.6	117±1.9
	Over.	102±5.4^{ab}	104±2.1^{a}	93±1.1^{b}	86±3.4^{b}	108±1.1^{a}
Pelvis width (mm)	F	21±1.8	21±0.8	21±0.4	26±0.7	20±0.4
	M	28±4.1	12±1.6	18±0.8	18±2.7	9±0.8
	Over.	24±2.2^{ab}	16±0.9^{ac}	20±0.4^{ab}	22±1.4^{b}	15±0.4^{c}
Drum length (mm)	F	132±4.0	128±1.7	132±0.9	60±1.5	127±0.8
	M	120±9.1	149±3.5	124±1.7	69±6.0	151±1.8
	Over.	126±5.0^{ab}	139±1.9^{a}	128±1.0^{b}	65±3.1^{c}	139±1.0^{a}
Shank circumference (mm)	F	96±3.7	65±1.6	98±0.8	43±1.4	65±0.7
	M	85±8.2	80±3.2	90±1.6	48±5.5	77±1.6
	Over.	90±4.5^{a}	72±1.8^{b}	94±0.9^{a}	46±2.8^{c}	71±0.9^{b}
Shank length (mm)	F	87±2.6	-	88±0.6	-	-
	M	83±5.9	-	83±1.1	-	-
	Over.	85±3.2		86±0.6		

^{abcd}Means with a different superscript in a row are significantly different ($p<0.05$) Adjusted p-values (Tukey-Kramer)

Table 6b: Least Square Means (LSM) and standard errors of body morphometric measurements for different chicken ecotypes in Vietnam

Trait	Sex	Ho (N = 102)	Ri (N = 9)	Dong Tao (N = 6)	Tre (N = 7)	Mia (N = 6)	Vietnamese crosses (N = 181)
		41	42	43	45	46	50
Body weight (g)	F	2840±59.5	1529±174.1	2100±265.9	575±226.1	1800±460.6	2320±49.1
	M	3855±71.1	2450±325.7	3833±265.9	717±265.9	2160±206.0	3001±47.8
	Over.	3347±46.3^{a}	1989±184.7^{b}	2967±188.0^{ac}	646±172.7^{d}	1980±252.3^{bc}	2661±34.3^{c}
Body circumference (mm)	F	322±5.1	261±15.0	283±22.9	194±19.9	280±39.7	307±4.2
	M	351±6.1	285±28.1	333±22.9	219±22.9	300±17.8	310±4.1
	Over.	337±4.0^{a}	273±15.9^{bc}	308±16.2^{ab}	207±15.2^{c}	290±21.8^{abc}	309±3.0^{b}
Wing length (mm)	F	219±2.7	201±8.0	190±12.2	130±10.5	180±21.1	219±2.2
	M	251±3.2	235±14.9	243±12.2	143±12.2	232±9.4	237±2.2
	Over.	235±2.1^{a}	218±8.4^{ab}	217±8.6^{b}	137±8.0^{c}	206±11.5^{ab}	228±1.6^{ab}
Back length (mm)	F	227±5.7	207±16.6	227±25.4	133±22.0	200±43.9	223±4.7
	M	255±6.8	233±31.1	260±25.4	145±25.4	232±19.6	238±4.6
	Over.	241±4.4^{ab}	220±17.6^{ac}	243±17.9^{b}	139±16.8^{c}	216±24.1^{abc}	231±3.3^{ab}
Breast width (mm)	F	94±1.8	94±5.2	87±8.0	63±6.9	100±13.8	95±1.5
	M	107±2.1	90±9.8	97±8.0	70±8.0	98±6.2	109±1.4
	Over.	100±1.4^{a}	92±5.5^{a}	92±5.6^{ab}	66±5.3^{b}	99±7.6^{a}	102±1.0^{a}
Keel length (mm)	F	144±2.6	124±7.5	113±11.5	250±9.9	160±19.9	132±2.1
	M	167±3.1	143±14.1	163±11.5	93±11.5	162±8.9	149±2.1
	Over.	155±2.0^{ab}	133±8.0^{bc}	138±8.1^{abc}	172±7.6^{a}	161±10.9^{abc}	141±1.5^{c}
Pelvis width (mm)	F	44±1.1	42±3.1	53±4.7	35±4.1	50±8.1	45±0.9
	M	35±1.3	20±5.8	43±4.7	40±4.7	31±3.6	30±0.8
	Over.	40±0.8^{ab}	31±3.3^{a}	48±3.3^{b}	38±3.1^{ab}	41±4.5^{ab}	37±0.6^{ab}
Drum length (mm)	F	178±2.3	144±6.8	157±10.5	94±9.1	190±18.1	163±1.9
	M	202±2.8	163±12.8	197±10.5	107±10.5	180±8.1	179±1.9
	Over.	190±1.8^{a}	153±7.3^{b}	177±7.4^{ab}	101±6.9^{c}	185±9.9^{b}	171±1.3^{b}
Shank circumference (mm)	F	142±2.1	111±6.2	120±9.5	70±8.2	60±16.4	134±1.7
	M	167±2.5	143±11.6	173±9.5	95±9.5	134±7.3	147±1.7
	Over.	154±1.7^{a}	127±6.6^{bd}	147±6.7^{ab}	83±6.3^{c}	97±9.0^{cd}	141±1.2^{b}
Shank length (mm)	F	-	-	-	-	-	-
	M	-	-	-	-	-	-
	Over.	-	-	-	-	-	-

^{abcd}Means with a different superscript in a row are significantly different ($p<0.05$) Adjusted p-values (Tukey-Kramer)

study. Average body weights for village chicken and crosses in the current study were 924±79.1, 1537±24.7 and 1069±24.7 g in Bangladesh, Sri Lanka and Pakistan, respectively. Among the Vietnamese chicken breeds, the Ho chicken was bigger and heavier than the rest of the breeds. The male and female Ho chicken have been reported to weigh 3692 and 2235 g, respectively (FAO, 2008), which is in agreement with the findings of this study.

Conclusion: In general, greyish mixture is the most dominant plumage colour, red the most common comb and earlobe colour, across the four study countries. Single combs, upright comb orientation, plain head shapes and not definite feather pattern are found in a higher proportion of birds across the countries. Majority of the birds do not have shank feathers. Apart from the naked neck, the rest of the birds had neck feathers.

The findings of linear body measurements show that birds in Vietnam were significantly ($p<0.05$) heavier and bigger, while those in Bangladesh are smallest. Birds in Pakistan are small in size but have significantly large back lengths. The weights and most body measurements varied significantly ($p<0.05$) across countries. Body weight measurements were significantly different across countries, except between Bangladesh and Pakistan.

The moderate variation in phenotypes among and within chicken breeds across the four study countries can be associated with geographical isolation and limited artificial selection pressure *in situ*.

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